ESSENTIALS OF MEDICAL ELECTRICITY

MORTON

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ESSENTIALS OF MEDICAL ELECTRICITY

KIMPTON'S ESSENTIAL SERIES

ESSENTIALS

OF

MEDICAL ELECTRICITY.

BY

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WITH ELEVEN PLATES AND SEVENTY ILLUSTRATIONS.

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PREFACE.

IN offering this little book to its readers, the author wishes it to be understood that he makes no claim to originality. On the contrary he makes every acknowledgement to the authors of those larger works which he has found helpful in its preparation—especially those of Dr. Lewis Jones in this country and Dr Rockwell in America—and also to his colleagues, from whom much information has been gained as a result of the constant association with them in hospital and private practice.

In addition to collecting together the *essentials* of the subject, the author has endeavoured to keep in view at all times the fundamental principles underlying the practice of electrotherapeutics and so the better to prepare the student for approaching the larger and more exhaustive works on medical electricity. Owing to the importance of studying the details of the curves produced by varying currents, a typical tracing of each class has been given in the hope that the characteristic features of each may be the more clearly demonstrated.

The author's best thanks are due to Messrs. K. Schall, Newton & Co., H. K. Lewis, The General Electric Co., Smith Elder & Co., and Leslie Miller for the loan of blocks, and also to Mr. Ernest Wilson, Clinical Photographer to the London Hospital for several photographs from which blocks were prepared.

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OF

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INTRODUCTORY.

In writing a book about anything it is customary to begin with a definition of the subject. This, however, is not possible in the case of electricity. No one has as yet formulated a satisfactory definition of electricity, and so far as we can at present foresee, there does not seem much probability of such a desirable event coming to pass. We know electricity only by its manifestations and it is from the study of these that the whole of our knowledge of the subject has been obtained. Electricity has been variously regarded as a fluid, a form of force, a manifestation of energy and so on. For medical purposes it is best to regard it as a physical agent like Heat and Light. In many respects electricity resembles a fluid in its behaviour, and the water analogy is very useful for purposes of illustration. Electricity exists everywhere but in such a state of perfect balance that we are unconscious of its presence. If we disturb this balance in any way it manifests itself in its efforts to resume the state of equilibrium. It is most important to remember that there is only one kind of electricity. By means of various mechanical and electrical devices it is possible to cause it to manifest itself in various ways but the difference is one of degree, not of kind. The three chief forms in which electricity manifests itself are (a) Static, that is in a state of rest (b) Constant or galvanic current,—in a state of flow more or less constantly in one direction, and (c) Induced or Faradic current—this is vibratory or alternating, the waves of which may or may not be symmetrical. Each of these forms is capable of being more or less further modified. For instance by means of a static machine, of which there are several forms, it is possible to generate and discharge numerous small quantities of static electricity in rapid succession so that it simulates, to a certain extent, a continuous flow. We can vary the pressure of the constant current at will and by means of interrupters render it intermittent or pulsating and as rapidly or slowly as we please. Further, the induced current can be modified in many ways which will be indicated later on.

CHAPTER I

STATIC ELECTRICITY

THIS is the oldest known form and was obtained by the ancients by rubbing certain substances together. If we rub a rod of glass and one of sealing wax together and then separate them we will find them capable of attracting each other and also light bodies such as small pieces of paper, cotton wool, etc. These effects are more easily produced if the glass be rubbed with silk and the wax with a piece of flannel or a dry catskin. These rods are said electrified. If two pieces of glass and two pieces of sealing wax or resin be electrified as above the following observations may be readily made.

(a) The two pieces of glass repel each other.

(b) ,, ,, ,, wax or resin repel each other.

(c) Each piece of glass attracts each piece of resin.

The glass is said to be positively electrified while the sealing wax is negatively electrified. From the above experiments we may deduce that like electricities repel and unlike electricities attract each other. It may be found futher that the degree of attraction or repulsion is proportional to the degree to which the bodies are electrified. Advantage is taken of this property in constructing an instrument called the electroscope by means of which we can tell when a body is electrified.

The Electroscope in its simplest form consists of two strips of gold leaf attached to the end of a wire. If a charged body is brought in contact with the wire—which must be carefully insulated from earth—a portion of the charge passes to the strips and being, similarily charged they repel each other. It is a delicate instrument and must be protected from moisture and air currents. It is for this reason usually enclosed in a glass jar. It is possible not only to find out if a body is electrified with this instrument but also to determine whether it is positively or negatively

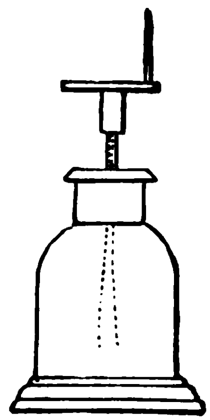


Fig. 1. Electroscope.

charged. The method is to transfer part of the electricity in the charged body to the electroscope by bringing it near or in contact with the wire projecting from the top—the leaves will diverge. Now take a glass rod which has been electrified by rubbing it with a piece of silk—positively charged—and bring it near the electroscope. If the leaves collapse the original charged body was negative and if they diverge still further—positive.

It must be remembered that when we by any means electrify any body, there is no creation of electricity. We merely disturb the normal electrical balance and produce an electrical separation. In the case of the glass rubbed with a piece of silk, we concentrate the positive electricity on the glass and a corresponding quantity of negative electricity on the silk. It is possible to construct a list of substances so that when any pair of them is rubbed together the body higher in the list is positively electrified and the other is negatively electrified to an equal extent. The following s a list of this kind, catskin, glass, flannel, paper, silk, shellac.

If we rub glass with catskin the glass becomes negatively electrified, while if the same piece of glass is rubbed with silk it is positively electrified.

Conduction.—We have seen that to charge the electroscope, we brought a charged body in contact with the projecting wire; a portion of the charge passed down the wire and so electrified the gold leaves. If we had suspended the leaves by means of a silk thread and applied the charged body to the distant end of the thread, no transference ot the charge would have taken place. There is thus a great difference in the behaviour of the wire and of the thread as regards electricity. In the case of the wire the charge was transmitted readily and is therefore a conductor. The silk thread does not do so and is consequently a non-conductor or insulator. All substances can be excited by rubbing with proper materials, but those which are conductors must be carefully insulated, otherwise the charge leaks away as quickly as it is produced. This explains why among the ancients the only electrical substances known to them were insulators or non conductors of electricity.

There is no sharp line of demarcation between conductors and non-conductors. The fact is all substances are conductors of electricity more or less, but some of them conduct it so exceedingly badly that they are practically insulators. A perfect insulator would be an absolute vacuum, but as an absolute vacuum exists only in theory—being practically unobtainable—we are at present without a perfect insulator. The following is a brief list of substances arranged in order of their conductivity:

Good Conductors	Poor Conductors	Insulators
Silver	Acid Solutions	Dry Skin
Copper	Saline	Pure Water
Platinum	Tissues of the body	Silk
Iron	The Skin—when moist	Vulcanite
Mercury	Tap Water	Glass
Carbon		Dry Air

The conducting power of some substances varies with their physical state. For instance, metals when heated offer a greater resistance to the passage of a current than when cold. Carbon, on the other hand, conducts better as its temperature is raised. Absolutely pure water is a very good insulator, but the addition of the slightest impurity brings down the resistance enormously. A person's skin when dry has a very high resistance, but when well wetted becomes a very fair conductor, again, dry air is one of the best insulators we know of—moist air is a poor conductor. Further, the insulating power of air is increased as its pressure is increased (plenum) while on the other hand as the pressure is decreased (vacuum) its insulating properties are decreased until a certain degree of vacuum is reached when it becomes a fair conductor, as seen in vacuum tubes (Geisslers'). If the degree of vacuum is carried beyond this point the resistance rises and its insulating power increases as the degree of vacuum is increased.

Induction.—If we suspend a pith ball by a fine silk thread and bring near to it a glass rod which has been rubbed with a piece of silk—positively electrified—the ball is attracted. If we bring the glass rod gradually nearer to the ball until it touches it, the ball is instantly repelled. The explanation of this apparent contradictory behaviour of the ball is—the ball was first attracted by the glass because the latter first *induced* a charge of negative electricity—electric induction—in that half of the ball nearest the glass—the other half being positive, and consequently as unlike electricities attract, the ball was attracted. As soon, however, as the ball touched the glass it became positively electrified, by conduction from the glass, and was repelled.

Instead of a pith ball we may experiment with a long hollow metal cylinder with closed and rounded ends and insulated, either by being suspended with silk threads or supported by glass pillars. If we now bring a positively charged body, also insulated, near to one end of the cylinder, that end will be found to be negatively charged and the further end positively charged. The charge will be greatest at the ends and will be found to gradually diminish until a point is reached at or near the middle when no charge of either kind can be detected. If now the positively electrified body is taken some distance away from the cylinder, the latter will resume its normal condition. If, however, while the charged body is near the cylinder the latter be momentarily connected to earth so as to discharge the first induced electrification, and then remove the charged body, the cylinder will be found negatively charged over its whole surface. "Acting inductively on an uncharged con-"ductor produces no change in it as a whole, but merely "induces equal and opposite charges on its two sides or ends" (Ayrton). The student must keep in mind that while we speak of developing positive electricity, or negative electricity it is not meant that two different kinds of electricity are produced though it is convenient to use that expression. It means that two different quantities have been developed, the positively charged body having more (+) and the body charged negatively having less (−) than its normal capacity.

In the above experiment the cylinder was described as having rounded ends. If a sharp point was fixed to each end, it would be found difficult or impossible to keep a charge in the cylinder for even a short time, so readily does a static charge leak away from sharp points. It is found that in any charged and insulated conductor other than a perfect sphere the density of the charge is not evenly distributed—the rule being that the density of the charge is greater as the curvature of the surface is greater, and in the case of a sharp edge or point the density is so great that discharge takes place.

Again, if an insulated body furnished with a point have its point brought near a positively charged body it becomes oppositely charged and the density of this induced charge becomes so great at the point that it will be discharged to the positively charged body, neutralising its charge and leaving the conductor which has the point positively charged. It is in this way the prime conductor of most electrical machines are charged from the revolving plate or cylinder.

Capacity. The quantity of electricity that is required to raise the potential of any conductor from zero to unity, all other conductors in the vicinity being kept at zero potential, is called its capacity—(Lewis Jones). The capacity of a conductor is determined by the extent of its surface since the charge exists only on the surface of charged bodies—consequently the greater the surface the greater the capacity. When we speak of a conductor having a certain capacity, that is not to say that it is capable of holding only a certain fixed charge. The amount of electricity that a conductor will hold depends on the pressure or potential at which it is charged. A conductor resembles an elastic bag in this respect—the greater the pressure used to fill the bag, the more it holds, up to the point of bursting.

The capacity of a conductor is also much increased by placing near to it other conducting bodies whose potential is kept at zero by being connected to earth—the nearer the earthed conducting bodies are to the conductor the greater becomes the capacity of that conductor.

Condensers. A condenser consists of two conducting surfaces separated by a dielectric or insulator. It is called a condenser because a given electro motive force can charge one surface—the other being connected to earth—with a larger quantity of electricity than if it stood alone. The capacity of a condenser depends on (a) The area of the surfaces—the greater the surface the greater the capacity, (b) The thinness of the dielectric—the thinner the dielectric the greater the capacity, (c) The material of the dielectric—glass has a greater capacity than the same thickness of air.

If the dielectric be too thin, sparks will pass between the plates, and if glass is used it will be perforated, or perhaps shattered, when the condenser is charged from a powerful electric machine. The simplest form of condenser consists of two metal sheets facing, and insulated from each other and from earth. If one of these plates be connected to earth and the other to the conductor of an electric machine the latter becomes charged. The most usual form of condenser is the well known Leyden jar which in its most common form consists of a glass bottle which is coated inside and out with tin-foil, and provided with a stopper of some insulating material through which passes a stout wire. On the outer end of this is mounted a metallic knob and from the inner end hangs a length of brass chain sufficient to make good contact with the inner coating. Here the two tin-foil surfaces are the conductors—sometimes called the armatures—and the glass the dielectric. The method of charging will be obvious from what has been said above.

The charge given to the inner coating acts inductively on the outer and is thus able to retain its charge. To discharge the jar a bent wire is placed with one end against the outer coating and while retaining it there the other end is brought gradually closer to the knob. Presently a spark passes and the jar is said to be discharged.

Fig. 2. Leyden jar.

As a matter of fact it is not completely discharged unless the wire has been brought in contact with the knob and the outer coating at the same instant, for if we try again to discharge the jar another spark will pass through much smaller and shorter than the first. This is due to the residual charge as it is called. It may be as well to mention here that when we discharge a jar, the spark is not single—passing once only from wire to knob or vice versa—what appears to be a single spark is really a series of sparks passing alternately in opposite directions, at enormous rapidity. This rapidity of oscillation may under certain conditions reach as high as thousands or even millions per second. The importance of this lies in the application of this property to the production of High Frequency currents which have attracted some considerable attention during recent years.

Static Electric Machines are used to generate a continuous supply of static electricity, and are of two kinds, frictional and inductive. The old-fashioned revolving glass-cylinder with an amalgamated leather rubber, and brass collector or prime conductor is an example of the frictional. type. Fig. 3.

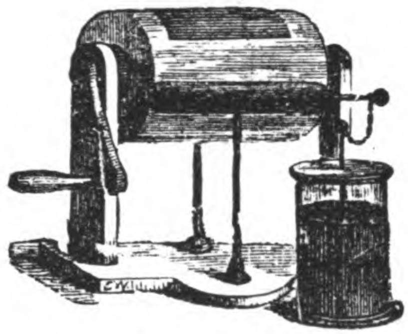


Fig. 3. Old type of Static machine with Leyden jar.

When the cylinder is revolved, positive electricity is developed on the glass and negative on the rubber—the latter is connected to earth and the charge thereby neutralised. The glass with its positive charge approaches the prime conductor and induces an equal negative charge on it. This negative charge streams off the points to the glass and so neutralises its electricity. By virtue of the electrical separation which thus takes place in the prime conductor the latter is left with a positive charge which may be used for any purpose required. These machines are not very reliable and often refuse to work in damp weather. Induction or influence static machines are much more reliable, but how they work is not easy to describe or understand. There are two principal kinds, the Holtz and the Wimshurst.

The Holtz machine is very popular in America but it possesses at least two distinct disadvantages. It has first to be given an initial charge from a small Wimshurst, before it will start generating and there is always the possibility of the poles reversing while it is in action. It is also somewhat sensitive to the changes of the weather.

The Wimshurst Machine is by far the most reliable of all. It is self-exciting and has no tendency to reverse during action, and on this account is most popular in this country. With some machines of this type one can never be sure beforehand which pole will be positive and which one negative, but once started the polarity will not change during the continuance of the run. It is not sensitive to changes of the weather to any serious extent. In very damp weather if it is not enclosed in an air-tight case its output will probably be somewhat reduced. Fig. 4. shews a small Wimshurst.

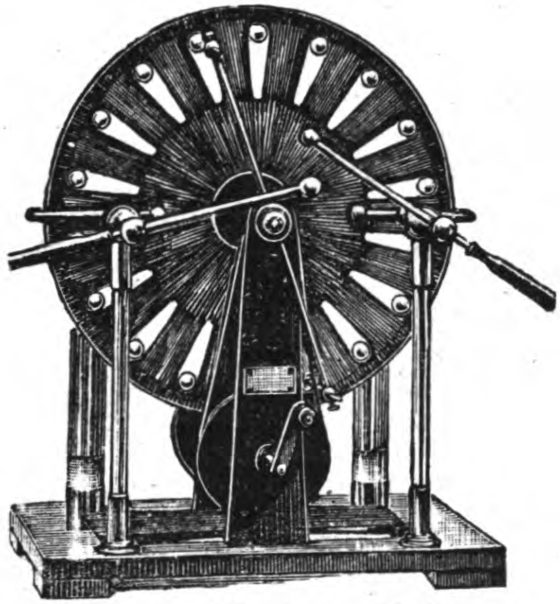


Fig. 4. Wimshurst Machine.

It consists in its simplest form of two circular glass discs each mounted on the end of a hollow boss of wood upon which a groove is turned to act as a pulley for driving the disc. The wooden bosses with the plates are mounted in a horizontal steel shaft so that the plates are facing each other and about one-eighth of an inch apart. Directly below the plates is another horizontal shaft upon which are secured two large wooden pulleys exactly opposite the grooves turned on the wooden bosses. A handle is provided at one end of the lower shaft and leather belts, one of which is crossed, fitted round each pulley and its corresponding boss. When the handle is turned the plates will revolve in opposite directions. The plates are well varnished, and attached to their outer surfaces are a number of radial sectors of tin-foil or thin brass. These are equally spaced all round the discs—they make the machine more easily self-exciting but are not essential to its action, especially in the case of larger machines. By means of a neutralising rod tipped with a fine wire or tinsel brush, mounted so as to be adjustable concentrically with the shaft upon which the plates revolve, each pair of sectors at opposite ends of a diameter are placed momentarily in metallic contact twice during each revolution. These neutralizing rods must be adjusted to the point of maximum efficiency, which will be readily found by experiment. If we stand facing the plate, and its direction of rotation be clockwise, the neutralizing rod will be in the position of the hands of a clock indicating *five minutes to five*. This will vary in different machines but the correct position will be found very near this point. The fixed conductors are mounted at the ends of the horizontal diameter and consist of two forks, with collecting points on the inside pointing towards each other, and the plates revolving between. These forks are mounted on ebonite or glass pillars, and the electrodes are attached to them. When the plates are revolved and the electrodes brought near together, a soft crackling discharge takes place. With a large machine this brush discharge may be many inches long, and forms a very striking object in a darkened room. As usually supplied, the machines have a Leyden jar attached to each electrode. When their outer coatings are connected together and the machine set in action the character of the discharge is completely altered. Instead of the soft crackling brush, the discharge takes place at definite intervals and each is accompanied by a more or less loud report. A shock from a large machine with the jars connected might be attended with fatal results. The jars are always to be disconnected before any static machine is used for treating patients.

There are made by some manufacturers various modifications of the Wimshurst. One has ebonite plates, and on account of the toughness and flexibility of the material, the plates can be driven at a very high speed. Another has plates made of compressed mica, which can also be driven at a high speed. The advantage of high speed is that the same difference of potential can be obtained with a smaller plate making the machine less bulky. The disadvantages of ebonite are that it often becomes bent and buckled out of shape. Also its insulating properties become very much impaired after a time, and the output of the machine correspondingly reduced. The micà plate machine has not been in use sufficiently long to form a correct opinion of its qualities. While glass is liable to split under disadvantageous conditions, its insulating properties are permanent, it has no tendency to alter its shape, and if the plates are correctly cut and mounted so as to run true, and the peripheral speed kept within the safe limit, it will be found the most satisfactory material we can employ.

Electromotive Force.—"Whatever produces or tends to produce a transfer of electrification is called electromotive force. Thus, when two electrified conductors are connected by a wire, and when electrification is transferred along the wire from one to the other, the tendency to this transfer which existed before the introduction of the wire and which when the wire is introduced, produces this transfer is called the electromotive force from the one body to the other along the path marked out by the wire."

The water analogy will perhaps help to make this more clear. If two vessels containing water be joined by a pipe and we increase the pressure in one of them the water will flow from the one in which the pressure is greater until the pressure in both becomes equal. Again, if one of these vessels be placed on a higher level than the other, the water will flow from the higher vessel to the lower until the balance is restored. In the same way, when any two electrified bodies are joined together by a wire, electrification will flow from the body of higher potential to the body of lower potential. The inherent force which starts and maintains the current is what is known as electromotive force—briefly written e.m.f. The potential of the earth is always taken as the zero of electric potential.

Volta's Contact Law.—A little over a century ago Volta made the discovery that when two dissimilar metals were brought into contact, a difference of potential was set up in the two metals, one becoming positively and the other negatively electrified. He found also that this difference of potential varied with the nature of the metals employed. Here again it is possible to draw up a list of substances—metals or conductors in this case—each of which will be positively electrified when brought into contact with any metal succeeding it, and negatively electfified with any metal coming before it in the list:—

+ Sodium
Zinc
Lead
Tin
Copper
Silver
Platinum
— Carbon

Carbon is not a metal, but is included in this list on account of its good conducting properties, and from the fact that it is now used so much in all branches of electrical work. If zinc and copper be brought together, zinc is positive and copper is negative, while if copper and carbon be brought together, the copper is positive and the carbon negative. The more one metal is removed from another in the list, the greater is the difference of potential. It will be noticed that those metals nearest the + end of the list are the most oxidisable, while the reverse holds good as regards the — end. Now, it might appear that when two dissimilar metals were brought together, and a difference of potential established, that this difference of potential would be immediately neutralised by a flow from the higher to the lower potential. This, however, is not the case, as a little consideration will show. When we take a bar of zinc and one of copper, as in fig. 5, and bring them together, an electric transference takes place in the direction of the arrow—the zinc being positive

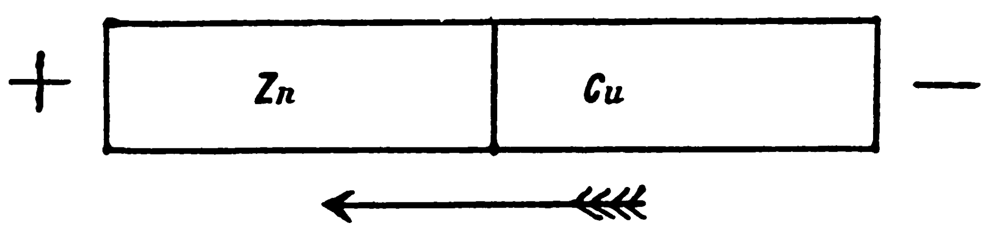


Fig. 5.

to the copper. To neutralise this difference a flow in the opposite direction would be necessary, but this cannot take place, in virtue of the fact that the contact tends to maintain a flow from the copper to the zinc. If instead of straight bars we use bars bent at a right angle, so that the two free ends can be dipped in some fluid, that is a conductor, and also capable of acting chemically on one of them, we will have formed a complete electric circuit—the difference of potential is continually renewed at the expense of chemical energy set up by the action of the fluid on the most oxidisable of the two metals—in this case the zinc. We have, in fact, constructed a Voltaic cell.

The Voltaic Cell.—Undoubtedly the best way of demonstrating the phenomena of the electric current is to construct a simple cell and study its action In selecting the materials for a Voltaic cell we choose one conductor from near the + end of the list of conductors given in the paragraph relating to Volta's contact law, and the other from near the — end.

The e.m.f. obtained by using sodium as the positive, and carbon or platinum as the negative is very high indeed, due to the very energetic chemical action set up. A plate of sodium is very expensive and is soon consumed, so that it is never used except perhaps as a laboratory experiment. The difference of potential set up in a cell composed of zinc and carbon, or copper, is considerably less, but as zinc is cheaper, lasts much longer, and is easily obtainable, it is practically the only electro positive metal used for primary batteries.

When we dip a strip of zinc in dilute acid, the zinc becomes negatively and the acid positively electrified. Platinum, under the same circumstances, becomes positively and the acid negatively, and copper acts in the same way, but to a lesser extent. If we immerse both zinc and copper the difference in potential is much increased, because we have then the sum of two potentials. To make a simple experimental cell, a strip of zinc and one of copper, a glass jar or jam pot containing some dilute sulphuric acid, about ten per cent. strength, and some copper wire will be required. A piece of copper wire about 12 inches long is soldered or otherwise secured to one end of each of the metal strips, and the latter are then immersed in the dilute acid in the jar. So long as

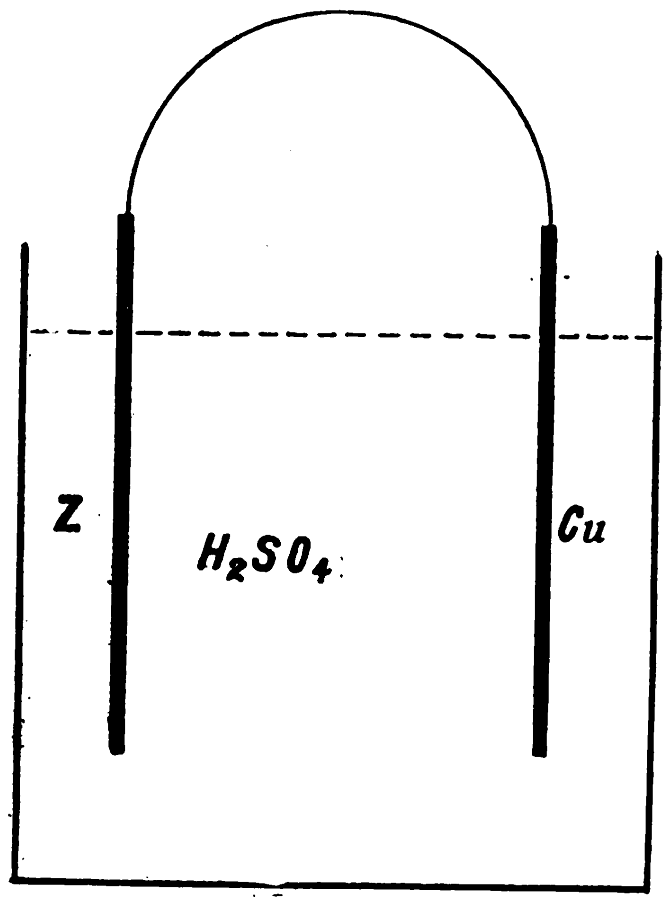


Fig. 6. Voltaic Cell.

the wires are not joined together very little action takes place. After a time the zinc plate will be found covered with minute bubbles of gas, which is of course hydrogen, some of which rises to the surface. A certain amount of zinc is dissolved, and passes into solution as $Zn\ SO_4$.

Owing to this chemical action, a fresh difference of potential is set up between the plates, and if we join the wires from the plates a flow of electricity takes place which tends to restore the equilibrium. As the chemical action is continuous so long as zinc and acid remain in the cell, the flow of current might be thought to continue at the same rate for the whole time.

It will be fouud that after the wires have been joined for a time the bubbles of gas are evolved from the copper plate. The molecules of hydrogen are still formed at the zinc plate, but are transferred to the copper plate by what is called electrolysis.

If we join the two wires to a galvanometer and leave them so, we will notice that the needle is at first considerably deflected, but after a time the amount of deflection becomes less and less, and it may even return to zero, indicating that no current is passing.

The explanation of this is that by the accumulation of minute bubbles on the copper plate the latter is practically transformed into a hydrogen plate, which is electro-positive to zinc, and tends to set up a current in the reverse direction. Also, the film of gas forms a layer of high resistance to the flow of the original current.

A cell in this condition is said to be polarised. The prevention of polarisation is one of the most important points in the design of a useful cell. The great variety of cells that have been devised have their origin in the various methods that have been adopted to overcome this tendency, and thus give as nearly as possible a constant current during their period of activity.

To return to our experimental cell:—How can we prove that electricity is present in the wires joining the plates outside the cell? As we know of the presence of electricity by its manifestations we can only ascertain if any of these manifestions are present. If we so arrange our cell that the wire joining the plates is in a line with the magnetic meridian, and bring a pocket compass close to it, either above or below the wire, the needle will no longer point north and south if a current is flowing through the wire. The north-seeking pole of the needle will be deflected to the east or west, according to the direction of the current, and whether the needle is above or below the wire. If we join the two wires through a very fine piece of platinum wire the latter will become heated. If we put the two wires on the tongue we get a peculiar burning and metallic taste, and if we pass the current through certain fluids they are decomposed.

These manifestations, the result of chemical action or other form of energy are due to what is generally termed the electric current. It should be remembered that we have no positive evidence that *anything* actually *flows*, or that there is what could be correctly described as a current. The term current, however, is the one most generally used, and most of the ordinary phenomena can be explained and followed on the assumption that there is a *flow* of energy along a conductor which manifests the presence of electricity.

There is one other peculiar manifestation of electricity when passing through a conductor that is not mentioned above. If we take a wire through which a strong current is passing, dip it into some iron filings and then remove it therefrom (the current still flowing), some of the filings will be found sticking to the wire, and will not all fall off when the wire is shaken, but if we stop the current flowing, they all fall away at once, and so long as the current is broken, the wire will not pick up any more. The reason for this is, that when an electric current flows through a wire there is always a field of magnetic force surrounding it. The lines of magnetic force are at right angles to the flow of current. This magnetic field is a necessary accompaniment of an electric current, and is inseparable from the latter. It is the presence of this magnetic field which causes the magnetic needle to be deflected in the way referred to above.

Magnetism:—The Magnetic Needle.—If a straight piece of hard steel wire, such as a knitting needle, be magnetised, and suspended so as to be free to move in any direction it will gradually come to rest with one end pointing to the north, and the other to the south. These ends are called the North pole and South pole respectively, and one is a necessary accompaniment of the other. That is to say, if we take any piece of magnetic substance, one end of which shows the presence of magnetism of the North variety—then the other end will be also magnetic, but of the South variety. If we take a bar magnet and cut it through at the middle where the magnetic attraction seems weakest or even lost, the result is two complete magnets, each having a North and a South pole.

The knitting needle arranged as above is merely another form of the pocket compass, and both are neither more nor less than bar magnets.

If we experiment with two bar magnets it will very soon be found that

(a) Like magnetic poles repel each other.

(b) Unlike magnetic poles attract each other.

In any magnet there are always a number of magnetic lines of force present, and outside the magnet itself these

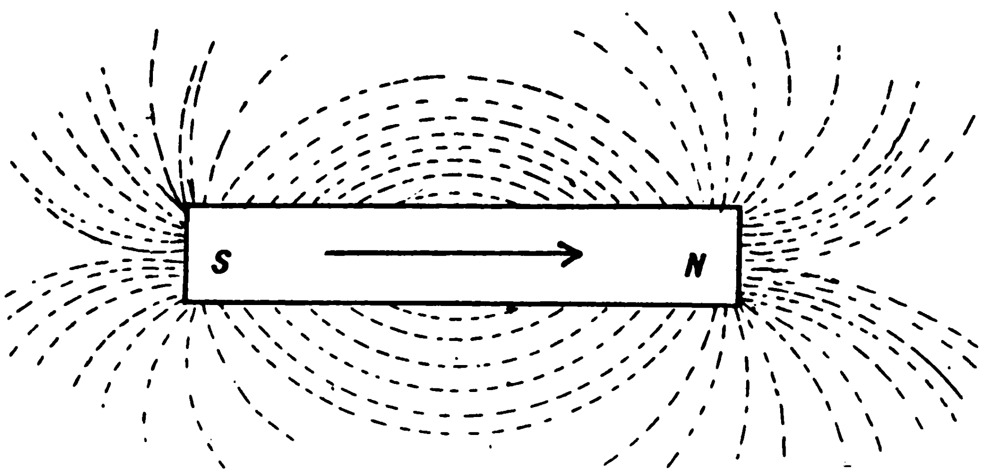


Fig. 7. Lines of force in a Bar Magnet.

lines of force are generally assumed to be flowing from the North pole to the South pole. The stronger the magnet the greater the number of lines.

If a bar magnet be brought into any magnetic field, and is free to move in any direction, it always tends to set itself so that its lines of force are parallel to those of the magnetic field. The earth is a big magnet with lines of force passing from the North to the South pole. This explains the action of the compass needle.

We have seen that a current of electricity flowing through a wire was always accompanied by a field of magnetic force, the lines of which are flowing at right angles to the flow of current. These, as in the case of the magnetic lines of a bar magnet, are assumed to have a certain direction depending on the flow of current.

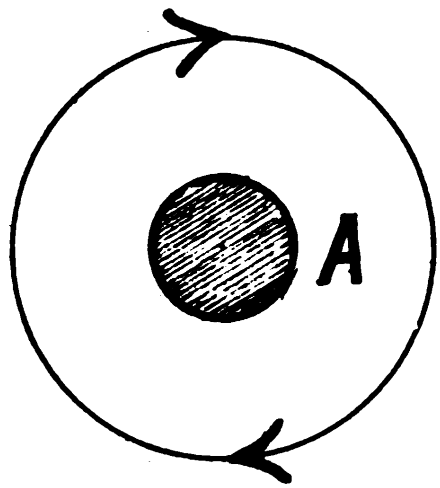


Fig. 8. Lines of magnetic force around a conductor.

In figure 8 we are supposed to be looking at the end of a conductor A, carrying a current which is flowing in the direction *from* the observer. Now, if we place a compass needle *over* the wire it will be affected by that part of the lines nearest it. The outer circle with the arrow heads represents the direction of rotation of the lines of force in the case of the current travelling as above. Above the conductor the movement is from left to right, and the North pole will turn towards the East.

If we place the compass needle under the wire, it is affected by that part of the lines which is moving from right to left, and the needle swings over towards the West. It is a help to remember this by the two words NOSE and SNOW. Thus:—

When the current flows from

(*a*) *N*orth
*O*ver to
*S*outh. North pole turns
*E*ast

(*b*) *S*outh to
*N*orth
*O*ver. North pole turns
*W*est

This is the principle of the action of the galvanometer.

The Galvanometer.—This instrument consists of one or more turns of wire with a small magnet suspended or otherwise mounted in the centre of the coil, so as to be free to move in any given plane—generally the horizontal. A light pointer is attached to the magnet or to the shaft upon which the magnet is mounted, so as to move with it. This pointer travels over a scale which is so graduated as to indicate the amount of current flowing through the instrument.

The currents used in medical electricity are so very small that something must be done to produce a strong magnetic field to move the needle sufficiently. This is done by increasing the number of turns of wire—some instruments used in medical electricity have hundreds or even thousands of turns. This gives a large deflection of the needle with a very small current flowing through the coil. The use of so many turns of fine wire introduces a certain amount of resistance into the circuit, but this generally is quite small when compared with that of the human body, which is included in the circuit.

Resistance.—We know that when a wire joins two points, between which there is a difference of potential, a current flows along the wire, and if we have an instrument called an ampere meter, or an ammeter, included in the circuit we can see at any moment exactly how much current is flowing.

Suppose we take a voltaic cell and join the two plates with a certain length of wire and the ammeter. The latter shows that a certain quantity of current is flowing, which we will represent by the figure 2. If we use a similar wire but of double the length of the former the instrument will point to 1 instead of 2. This is due to the extra difficulty the current experiences in getting through the longer wire; that is, to the greater resistance of the circuit.

The resistance of a conductor depends on certain conditions.

It varies

(a) Directly as the length.

(b) Inversely as the area of the cross section.

(c) With the nature of the material of which the conductor is made.

(d) To a certain extent with the temperature.

(a) and (b) are sufficiently obvious. With regard to (c) a conductor made of silver is found to have the lowest resistance when compared with one made of any other material of similar shape and size. The resistance of copper is very slightly greater than silver. Platinum has a resistance about six times greater than silver and iron about nine.

As a rule alloys have a resistance much greater than pure metals. An alloy known as German silver has a resistance about fourteen times greater than silver, while another called rheostene has about forty-four times the resistance of copper. Speaking generally the resistance of metals increases with an increase in temperature. Carbon and electrolytes decrease in resistance as the temperature rises.

In speaking of resistance it is useful to have a unit so as to be able to compare the resistances of various circuits or the different parts of a single circuit. The unit of resistance is called the Ohm after the scientist who formulated the law which is known by his name. An Ohm is represented by the resistance of a column of pure mercury at O°C. of a uniform cross section of one square millimetre and 106 centimetres long.

Ohm's law is as follows:—

"The strength of the current in any circuit or part of a circuit, varies directly as the electromotive force in that circuit and inversely as the resistance of the circuit.

Expressed in symbols it is:—

$$C = \frac{E}{R}$$ where

C = The current.
E = Electromotive force.
R = Resistance.

From the above equation we obtain

$$E = CR$$

and

$$R = \frac{E}{C}$$

so that with any two of the factors given the value of the third is obtainable by a simple calculation. This is probably the most important law that has been laid down relating to electricity, and is one that the student should work at until he is thoroughly familiar with it in all its aspects. It underlies every intelligent application of electrical science.

Practical Units.—We have seen that the *ohm* is the unit of resistance. It will of course be obvious that we will require other practical units upon which to hang our calculations.

ElectroMotive Force.—The unit of e.m.f. is called the volt. It very nearly corresponds with the e.m.f. of one Daniell's cell.

Current.—The unit of current is the *ampere* and is that current resulting from an e.m.f. of one volt acting through a resistance of one ohm. A current of one ampere flowing for one hour is one ampere hour.

Quantity.—The unit of quantity is called the coulomb and is represented by one ampere of current flowing for one second.

The Watt.—Is the unit of *work done* at any moment in a circuit. It is the product of the volts by the amperes. A current of one ampere at a pressure (e.m.f.) of one volt flowing for one hour is called *one watt hour*. The Board of Trade unit as used by all supply companies is 1000 watt hours. A current of ten amperes at one hundred volts flowing for one hour represents 1000 watt hours, for which the usual charge is sixpence. This is not a unit used in medical electricity but as many will obtain their supply from the street mains it is as well to know what a Board of Trade unit really means.

Capacity.—The unit of capacity is called the Farad, and represents that capacity which is charged to one volt by a current of one ampere flowing for one second.

In medical electricity we have to deal with very small currents and comparatively high resistances. The average resistance of the body is about a 1000 ohms, while the amount of current we employ is expressed in so many thousandths of an ampere—the thousandth part of an ampere is called the *milleampere*, and is the unit of current used in medical applications.

Poles.—In any battery, the plate most acted upon is the positive. As a help to remember the course of the current in a circuit, we might say the current *starts* where the most active chemical action is taking place, runs across to the other plate and round the external conductor to the positive plate. It is important to distinguish between *plate* and *pole*.

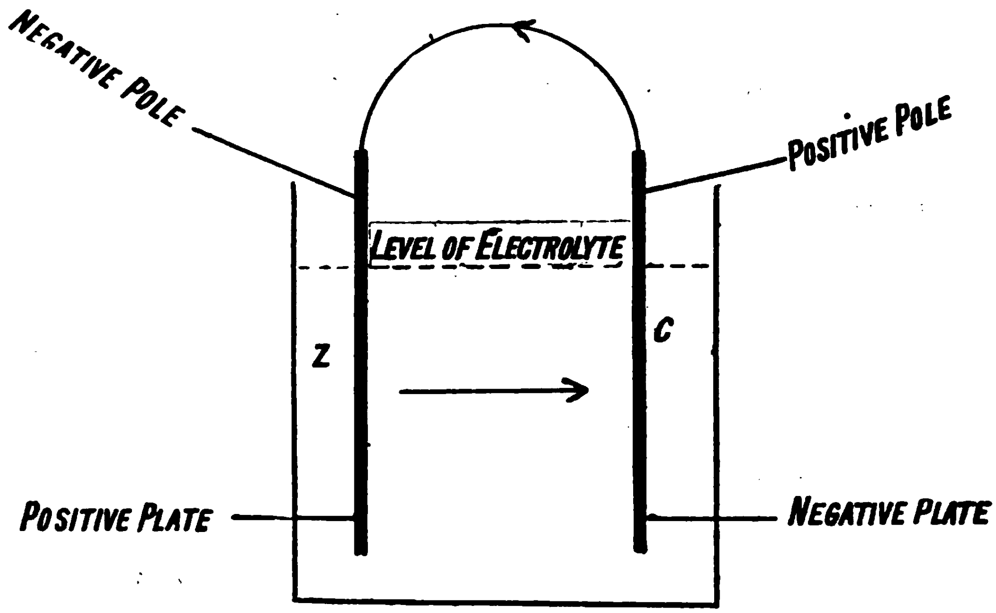


Fig. 9.

In fig 9 that part of the circuit within the fluid of the cell is called the internal circuit, while that outside is the external circuit. In any circuit or part of a circuit, that part from which the current is coming is positive to a part to which current is flowing.

Bearing this in mind it will be seen that that portion of the zinc which is below the level of the fluid is positive to that part of the copper which is also below the level of the fluid. In the external circuit we see that the part of the copper outside the liquid is positive to the corresponding part of the zinc. These *dry* portions of the plates are called the poles. If we attach a wire to each of these, the free extremities of these wires becomes the poles.

Thus it will be seen that the wet portion of the zinc is the *positive plate* and the dry portion is the *negative pole* while the wet portion of the copper is the negative plate, the dry portion is the positive pole. This may seem very confusing, but it is not really so, and if the student will take the trouble to get the idea thoroughly, there is little chance of his being confused by any of the various arrangements of circuits, he will meet with in future.

It is customary when referring to the plates of a battery to speak of the *poles* and not of the *plates*. The zinc is thus the negative pole and the other element, be it carbon, copper, or platinum is the positive pole.

Electrolysis.—The fluid of a cell is called the electrolyte. An electrolyte has been defined as a compound substance which conducts electricity by virtue of simultaneous chemical decomposition.

It differs from a conductor, in that the latter undergoes no chemical change during the passage of the current

The process of decomposition of an electrolyte by means of the electric current is called electrolysis. Some knowledge of this process is necessary for a proper understanding of the physiological and therapeutical action of electricity. In electrolysis we generally employ metal plates connected by wires with the poles of the battery or other source of supply. These plates are preferably made of platinum. That plate which is connected with the positive pole is called the *anode*, the other, connected to the negative pole is the *cathode*. The particles given off at the plates are called the *ions*. This process of electrolysis has been receiving a great deal of attention in recent years, and the following is a brief outline of the latest theories regarding it.*

(a) Solution pressure:—The tendency of a body to go into solution may be called its solution pressure, and the different degrees of solubility possessed by different salts may be spoken of as differences in their solution pressures.

The solution pressure of any particular salt is constant

* From Medical Electricity, H. Lewis Jones, M.D., 4th Edition.

under any given set of conditions but varies definitely with any definite change in their conditions.

(b) Osmotic pressure.—When a soluble substance is placed in water it goes into solution at first rapidly, but as the solution approaches saturation it dissolves more and more slowly. The dissolved molecules appear to exercise a pressure which opposes the solution pressure and eventually a point of equilibrium is reached when the opposing pressure of the dissolved particles equals the solution pressure of the substance This back pressure is known as osmotic pressure and is susceptible of accurate measurement.

The whole class of compounds known as electrolytes break up or are dissociated when dissolved in water. Sodium chloride for example breaks up more or less completely into the two separate parts, sodium and chlorine, zinc sulphate into Zn and SO_4 and so on, each molecule forming two separate entities which are known as *ions*.

The ions carry definite charges of electricity, those of the metals carry positive charges those of the non-metals (chlorine, acid radicals, etc.), carry negative charges. The ions SO_4 H. Na. etc., do not manifest the chemical properties of their elements as ordinarily recognised. The difference is one of their electrical charges, and when the ions are deprived of their charges the element reappears in its ordinary form. In the solution the ions are equally diffused and the positive electricity of the one set exactly neutralises the negative electricity of the other set, so that the dissociation of a salt does not affect the apparent electrical condition of the solution.

If these conceptions be applied to the case of metals immersed in solutions, it is found that they possess the property of passing into solution and of forming ions. This special tendency of metals to dissolve with the formation of ions, is called their electrolytic solution pressure to distinguish it from the simpler solution pressure of salts. Just as osmotic pressure opposes solution pressure so it opposes electrolytic solution pressure. In the case of a metal immersed in a solution of its own salts the osmotic pressure of the ions of the metal already in solution tends, in proportion to their number, to prevent the passage of fresh ions of the same kind into solution. The formation of ions from a metal requires definite, positive, electrical charges, and if ions are formed when a metal is immersed in a liquid they must exist in the solution without any balance of negatively charged ions such as are formed when a salt like Na Cl or ZN SO_4 is dissolved Consequently the liquid must acquire a positive charge, and as both kinds of electricity must be simultaneously developed whenever electrical energy comes into existence the metal acquires an equal negative charge. Electrical equilibrium is thus maintained, but the tendency of the metal to continue forming positive ions is opposed. It has been observed experimentally that certain metals become negatively charged when immersed in an electrolyte, while others require a positive charge. Those of the former class have an electrolytic solution pressure which is large and have a strong tendency to form ions, and those of the latter class have an electrolytic solution pressure which is low, and with them ionisation does not take place except with special electrolytes.

Those metals whose electrolytic solution pressure is greater than that of hydrogen are able to deprive hydrogen ions of their positive charges and thus to displace hydrogen in an electrolytic cell. They are the metals which dissolve in acids with evolution of hydrogen gas. In the case of the Voltaic cell we have an electrolyte, H_2 SO_4 in which two dissimilar metals, zinc, and copper, are immersed, it will be seen that each will exert its own solution pressure and become positively or negatively charged. The zinc by virtue of its high electrolytic solution pressure tends to form positively charged zinc ions and in doing so becomes negatively electrified. The copper has almost no tendency to become ionised and acquires a positive charge. On joining the two metals by a wire an electrical circuit is formed. The copper communicates its positive charge through the wire to the zinc and the zinc is thereby enabled to supply positive charges to its ions, which accordingly go into solution, the hydrogen of the electrolyte gives up its positive charges to the copper and appears at the surface of the copper in the form of bubbles; the SO_4

ions remain unaffected. So long as Zn ions continue to go into solution. and hydrogen ions continue to give up their charges of positive electricity to the copper the current of electricity flowing in the wire from copper to zinc will continue, but as the liquid becomes richer in zinc ions, then osmotic pressure will begin to oppose the electrolytic solution pressure of the zinc. Also as the free available hydrogen ions diminish through being expended the renewal of the positive charge of the copper will begin to fail and the action of the cell will fall off.

Internal Resistance.—This refers to the resistance to the flow of current inside a generator or originator of an electromotive force. In the case of a dynamo-electric machine it is the resistance of the copper conductors with which the machine is wound,—and in the case of a battery, it is the resistance of the electrolyte between the plates. In the former case it depends on the length and size of the conductor; in the latter, on the nature of the electrolyte, the area of the plates, and their distance from each other. For a generator to have a large output it is essential that its internal resistance be kept very low. A resistance inside a cell has to be overcome just the same as if it were in the external circuit, and where the external resistance is very low, a high internal resistance would have a very serious effect on the output of current. On the other hand, with a very high resistance in the external circuit the internal resistance does not signify very much on account of the small proportion it bears to the total resistance of the circuit. To take an example:—if the internal resistance of a cell be 3 ohms, and the resistance of the external circuit be 1 ohm, three-fourths of the e.m.f. of the cell will be used up in overcoming its own resistance, leaving only one fourth of the original e.m.f. available for the outer or useful circuit. If, again, the internal resistence be the same, and the external resistance be 97 ohms, then only $\frac{3}{100}$ of the e.m.f. will be used up inside the cell leaving $\frac{97}{100}$ available for the outer circuit. In the first example 75°/。 of the total e.m.f. was wasted in the cell, in the second only 3°/。.

Arrangement of Cells.—If we have a number of cells of any kind we can join them up in various ways to suit our requirements. Suppose we have twelve cells, each of which is capable of supplying a current of 1 ampere at an e.m.f. of 1 volt. It will be more convenient for the sake of clearness to assume that the cells have no internal resistance. We will also suppose that we have a 12-volt incandescent lamp with which we wish to examine some part or cavity of the body. This lamp requires an e.m.f. of 12 volts to bring it to full incandescence. To obtain this we join the positive pole of the first cell to the negative of the second, and the positive of the second to the negative of the third, and so on to the end of the row so that we have a free negative pole at the first cell, and a free positive pole at the twelfth, thus:

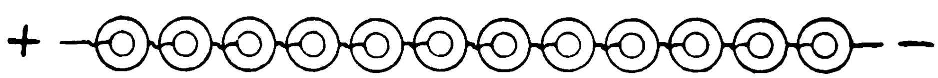


Fig. 10. Series Arrangement of cells.

If we now connect a voltmeter to the two wires from the ends, the instrument will register 12 volts, and if we replace the voltmeter by the lamp it will light up to its full candle power.

The cells as above are said to be arranged in *series*, and the effect of the arrangement is to increase the voltage directly as the number of cells—the total e.m.f. being equivalent to the e.m.f. of one cell multiplied by the number of cells. It does not increase the number of amperes beyond what is available from a single cell, that is one ampere, which is probably more than the lamp requires. Now suppose we have a cautery which it is desired to use to remove a naevus or other growth, and that it has a resistance of $\frac{1}{12}$ ohm and requires a current of 12 amperes to bring is to the proper heat. It is quite clear that the series arrangement will not do, as the amount of current available is quite insufficient to affect the cautery. Also it will be seen that an e.m.f. of 1 volt is all that is necessary to send a current of 12 amperes through a resistance of $\frac{1}{12}$ ohm. Thus we have no object in increasing the volts beyond that given by one cell, but we do want to increase the amperes available from each cell so as obtain a current of 12 amperes. We now join all the positive poles together and do the same with the negatives, thus:

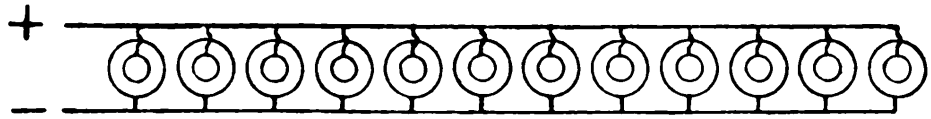


Fig. 11. Parallel arrangement of cells.

The result here is the same as if we had one big cell twelve times the capacity of a single cell. The voltage of any given cell is the same whatever the size, but the larger the cell the greater the quantity of current it is capable of supplying. We will now find that the difference of potential between the terminals of the arrangement is just one volt, but if we connect up the cautery it will glow a bright red and be ready for use. The cells connected as above are said to be arranged in parallel.

Various combinations of the series and parallel arrangements are also possible. If we wanted a current of 2 amperes at a pressure of 6 volts, we would arrange the first six cells in series, and also the second six cells in the same way, and then join these two sets in parallel. This is a series-parallel arrangement,—other modifications of which will suggest themselves.

Density.—By density we mean the amount of current passing through or concentrated upon any given area. We have seen in our induction experiments that, in a long metal cylinder with closed and rounded ends, the electricity was not evenly distributed over its surface, there was a greater density of charge where the curvature was greatest. In medical applications where electrolytic changes are not desired, we have to avoid any excessive density of current, if only for the comfort of the patient at the time. If we wish to employ large currents we must use large electrodes, and see that they are well adapted to the part. For example, if we wished to apply a current of 50 milleamperes to a limb, and used electrodes, say one inch in diameter, the patient would experience a very sharp pain at the points of contact, and if the application be persisted for some minutes, a blister or even an ulcer will eventually form. The reason being that the whole 50 milleamperes passes through an area 1 inch in diameter. If we use larger electrodes of, say 5 inches in diameter, the current density instead of being 50 m.a. per inch, would be only about 2 m.a. per inch. In this way we can employ the same amount of current without discomfort or harm to the patient.

The Electromagnet.—It was shown that a wire carrying an electric current became magnetic and would attract iron filings. If we take a piece of soft iron rod and wrap this wire around it, it will impart its magnetism to the iron, which will become strongly magnetic, especially if the wire is wrapped many times round and a strong current sent through it. This arrangement constitutes an electromagnet. Electromagnets are only magnetic when an electric current is traversing its wire helix, provided the core—as it is called—is composed of *soft* iron or *soft* steel. Magnets on this principle can be made capable of lifting many tons weight. They lose their magnetism entirely when the current is cut off. If the core should be made of very hard steel, a portion of the magnetism remains after the current is cut off. This core may be removed from the centre of the wire winding, and will retain more or less of its magnetism indefinitely. In this way permanent magnets are made.

Electro-magnetic Induction.—The first observations of this most interesting and important subject were made by Faraday. He found that in a closed circuit a current is induced as often as a magnet is approached to this conductor or withdrawn from it. He also found that if a current were made to pass through another circuit near, but quite detached from the first one, a momentary current passed through the latter, both when the current was made and when it was broken. The current is produced by virtue of the magnetic field set up and removed in the neighbourhood of the original closed circuit. These induced currents as they are called, only appear so long as the magnetic field is varying in strength. The current induced at the starting of the inducing current is in an opposite direction to the latter and that produced when the inducing current is broken is in the same direction as the inducing current. It will thus be seen that whether we use a permanent magnet, an electro-magnet or a length or coil of wire carrying a current for our purpose, so long as we subject a closed circuit to a varying field of magnetic force, currents of electricity are set up in the closed circuit which currents will vary in direction of flow according as the magnetic field is increasing or decreasing in strength.

Simple as the fundamental principle of induced currents is, it is perhaps the most important of all as regards the practical applications of electricity. The dynamo, motor, induction coil, telephone &c, are all based on the principle of electro-magnetic induction.

Self-Induction.—If we take a length of insulated copper wire, say two or three yards, straighten it out and attach one end to one terminal of a battery cell possessing high internal resistance such as a Leclanche. Bring round the other end (both ends must be stripped of their insulated covering for an inch or so) and touch the other terminal of the cell with it for a moment. A very tiny spark will be seen at the instant the wire leaves the terminal. It may be necessary to do this experiment in a darkened room so small is the spark. Now coil up this length of wire into a close spiral by winding it on a ruler, and repeat the above procedure; the spark will be increased in volume. This is due to the magnetic induction of the turns of the spiral on each other. When the spiral joins the two terminals of the cell the full amount of current does not get through the wire so rapidly because as the current is rising in the turns they induce currents in each other which tend to *oppose* the incoming current. Consequently if the contact were made for a *very* short period of time, the spark might be smaller than before. As we are performing the experiment, plenty of time will have been given for the current to rise to its full value. At the instant of breaking contact the turns induce on each other a current in the same direction as the incoming current. It reinforces the latter to such an extent that a brilliant spark is produced as the current is completely broken. This is due to what is called Self-Induction. If we insert a rod of iron in place of the wooden ruler and repeat the experiment these effects are still further increased. We can vary the amount of this self-induction current by increasing or decreasing the number of turns in the spiral, by varying the strength of the original current, and by inserting or withdrawing an iron core.

A hollow spiral of wire is called a solenoid, and when traversed by a current of electricity has all the properties of a magnet. When a rod of iron is inserted into it, all its properties are intensified. It becomes in fact an electro-magnet.

In view of what has been said above it will not be difficult to see that a solenoid with a considerable number of turns, enclosing an iron core, will, when supplied with a current which rapidly alternates in direction, set up such strong self-induction currents as to oppose the incoming currents to an extent out of all proportion to the resistance of the wire composing it. Again, if we take an iron core made in the form of a closed square or parallelogram or even a circle and wind a coil on one side of this and apply an alternating current to it, the result of course is the same.

Transformer.—Now let us wind another coil on the opposite side of the core which we will call the secondary coil—the other is of course the primary. If we connect the primary again with the alternating current we will find that another alternating current is formed in the secondary coil. This is in fact an experimental transformer and differs in no essential particular from those used for the distribution of electrical energy where ever alternating currents are used. The primary coil impresses a magnetism on the core which is constantly varying. As the core is continuous and passes through both coils, the secondary coil is thus exposed to a constantly varying magnetic field. We have already seen that the effect of this on a conductor is to set up currents of electricity in it. It will also be found that we can vary the voltage or pressure of this secondary current to any extent we please. It is simply a question of the number of turns employed as compared to the number of turns on the primary. This will be best explained by an example. Suppose our primary coil has one hundred turns of wire and the alternating current supplied to it has a mean pressure of 100 volts, and we wish to obtain a current to heat a cautery which requires a pressure of say 5 volts. The primary has one turn per volt and theoretically the same will be right for the secondary—in this case five turns. It will be found that this will come out about right, and if the wire of the secondary has been chosen sufficiently thick plenty of current will be available for even the largest cautery used in surgery. A transformer regulates itself in a most perfect manner. As we draw off current from the secondary this relieves the primary of so much of its self-induction, and consequently more current flows in. In a well designed transformer very nearly the same amount of energy is available from the secondary side as is supplied to the transformer on the primary side. Supposing we have one which is designed to take 10 amperes at 100 volts through the primary. This is equivalent to 1000 watts. According as the secondary is wound we can have from it 200 amperes

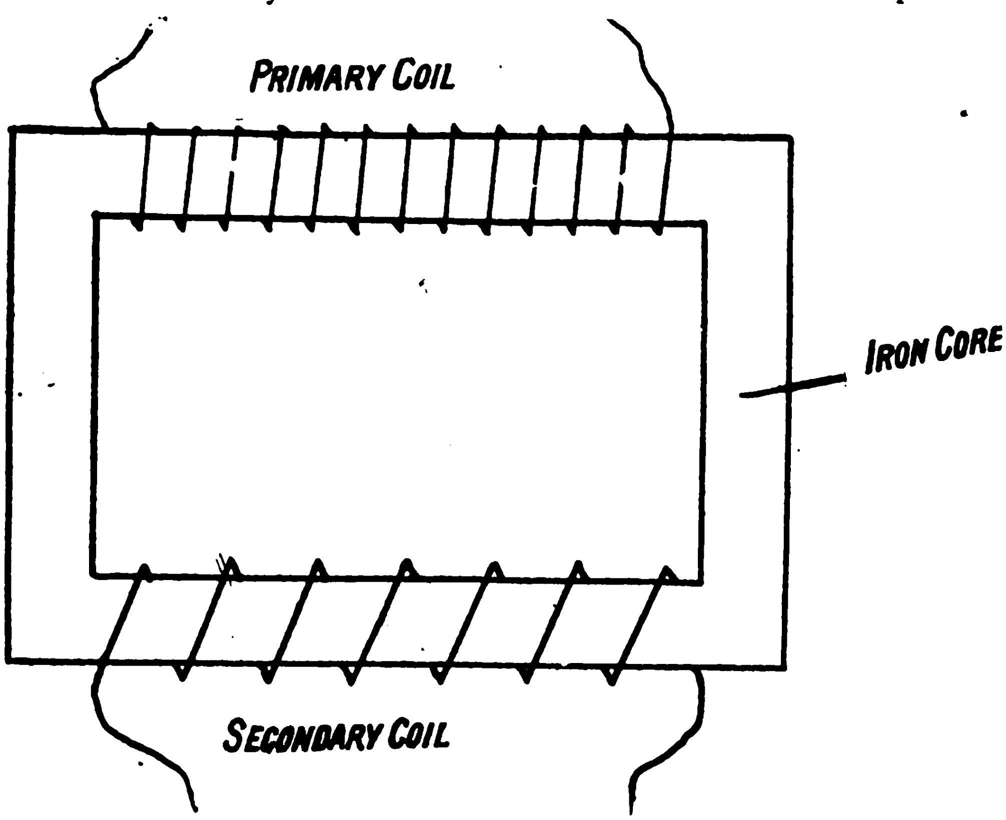


Fig. 12. Diagram of Transformer.

at 5 volts, 1 ampere at 1000 volts, or 0·1 ampere at 10·000 volts. The alternating current transformer is the most efficient instrument we possess. For those who have an alternating current available, a transformer which will give any voltage desired is a most useful appliance and will well repay any trouble or expense incurred in obtaining it. The author has one which is very satisfactory. The primary is adapted for 100 volts which is most often available whenever the alternating current is used. The secondary is so arranged that any voltage from 1 to 80 can be obtained in a moment. Thus it can be used for heating cauterys, lighting small lamps for illuminating purposes, electrical treatment, baths, etc.

Alternating Currents.—As the name implies, an alternating current is one in which the direction of flow is constantly alternating. The pressure or voltage rises from zero to a maximum—depending on the mean pressure—falls again to zero, when immediately a reversed current takes place, which goes through the same series of changes, thus completing the cycle. The voltage curve for any alternating current can be plotted out by instruments made for the purpose. In a well designed machine this curve comes out practically as a true sine curve. Such a

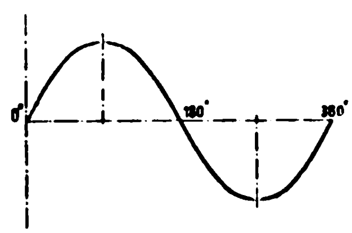


Fig. 13. Double Sine Curve.

a curve is called sinusoidal. The figure shows the curve for one complete cycle. The "frequency" or periodicity of an alternating current refers to the number of these complete cycles per second. Frequencies used to be from 100 to 130 per second, but lately lower frequencies has become much more common—from 40 to 60. The symbol ∿ is used to designate an alternating current, and "50 ∿" would mean an alternating current having a frequency or periodicity of 50 cycles per second.

While it is possible to evolve a sinusoidal current directly from an ordinary battery current, we may say that all alternating currents have their origin in a dynamo machine. When a closed circuit is rotated between the poles of a magnet an alternating current circulates in it, there being one complete cycle for each revolution.

The Dynamo.—It is a fair estimate that over 99 °/ₒ of the electricity used is obtained from dynamos. The dynamo is a device for converting mechanical into electrical power. It consists of three essential parts. (a) The field magnet, (b) The armature, and (c) The commutator and collecting brushes.

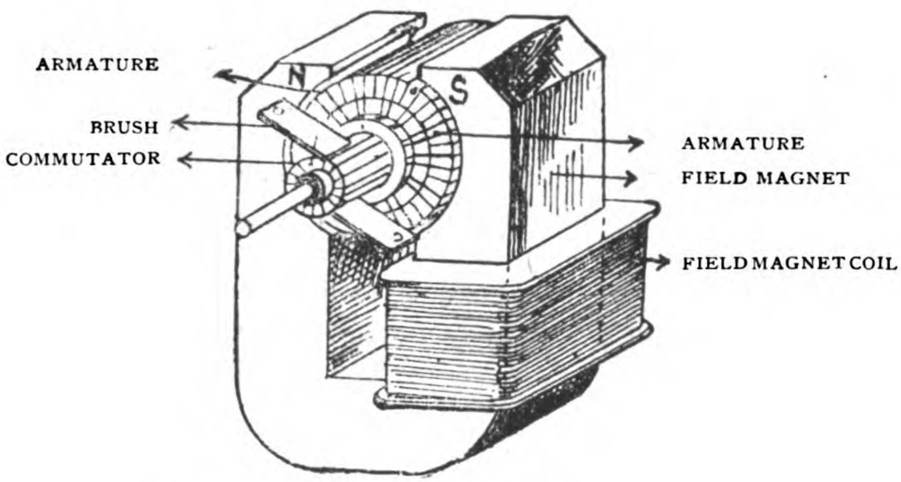
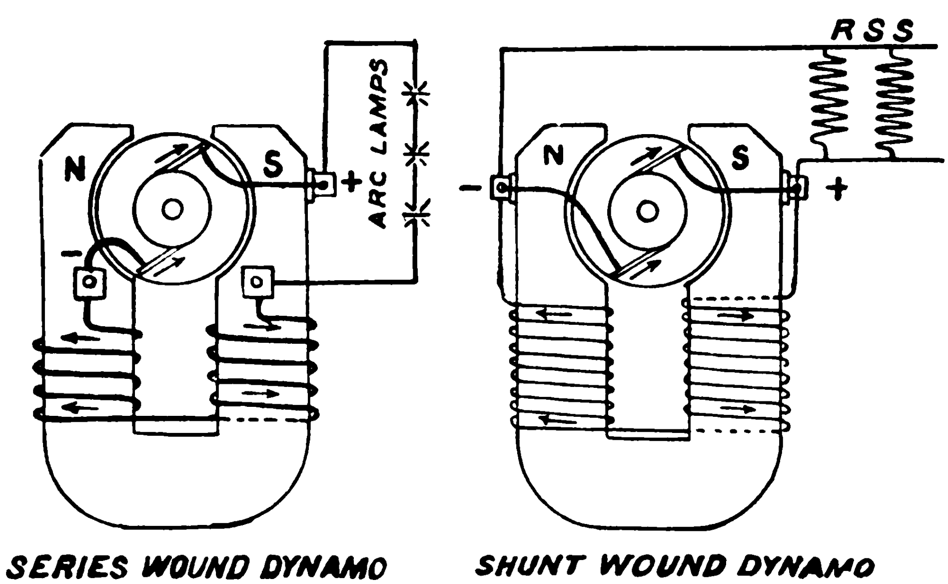


Fig. 14. Parts of a 2-pole Dynamo.

(a) The field magnet, which generally forms part of the framework of the machine, is usually an electro-magnet, the poles of which have their opposing faces hollowed out to the arc of a circle, in which space the armature revolves. When the field magnet is excited this space will be the seat of a powerful magnetic field. The essential point about the field magnet is that its poles never change; one is always north and the other is south.

(b) The armature consists of an iron core, upon which are wound one or more closed conductors, and is so designed as to completely fill the space between the field magnet poles, leaving just sufficient room for it to revolve without touching. It has been shown that to rotate a closed conductor in a magnetic field is to set up an alternating current in it—so to rectify this alternating current the third essential part is devised.

(c) The commutator. This consists of a number of copper bars mounted in the form of a cyclinder, and insulated from the shaft and from each other. There are as many bars as there are coils on the armature. The beginning of one coil and the end of the coil just preceding it are joined together, and the two attached to a commutator bar. Two brushes of copper gauze or carbon are arranged to touch the commutator at opposite ends of a diameter; and as the armature is revolved the commutator bars pass in succession under the brushes which collect the current from them. Most dynamos which have a commutator are arranged so that the whole or part of the current generated in the armature passes round the field-magnet, and are thus self-exciting. The iron of the field magnet always retains a small amount of permanent magnetism. This is sufficient to give rise to a small initial current in the armature, which circulating round the field magnet coils gives rise to a stronger current in the armature, and so on, until the full power of the machine is attained. If an alternating



Figs. 15 and 16.

current is required, the armature winding is tapped at diametrically opposite points and the ends connected one to each of two slip rings which are also insulated from the shaft and from each other and by means of brushes the alternating current generated in the armature is collected. In the case of a very small alternator one or more permanent magnets may be used for the field magnet. This is the case in the magneto machines which are still to be found, chiefly in the hands of the public for self-treatment in their own homes. Their therapeutic value is very limited.

The direct current dynamo is a reversible machine, that is to say, it will not only generate electricity when driven from some source of mechanical power, but if supplied with electricity from any external source it will give back the energy in the form of mechanical power. The dynamo and motor are structurally the same—a good dynamo will give good results as a motor and vice versa. Direct current dynamos are divided into two main classes—series and shunt. In the former the whole current generated in the armature traverses the field magnet coils as well as the external circuit. In the latter only a portion of the armature current is shunted through the field coils, the rest being available for the external circuit. Each has particular advantages for certain classes of work. The arrangement is shown in Figs. 15 and 16.

CHAPTER II

SOURCES OF SUPPLY

It having been decided to follow up the study of medical electricity, the first question which arises is that of supply.

The following are the most available and will be dealt with in order.

(a) Current from the main.
(b) Dynamo and driving plant.
(c) Accumulators.
(d) Primary batteries.

(a) **Current from the main.**—This is the ideal source and will be taken advantage of by all to whom it is available. The usual pressure at which it is supplied is 100 volts, but with the increasing demand for electricity a gradual change to 200 volts or more is taking place. This renders it possible to transmit double the energy through the same size of conductor.

It is not so economical in practice to the consumer nor is it so convenient for medical work.

The current from the main may be constant or continuous, or it may be alternating. Whichever it is must be found out, as also the voltage, before anything can be done in the way of equipment.

The Direct or continuous current is the one most useful for medical work. The first thing required is some means of reducing the pressure. This can be done by resistances in series with the patient, but it is not the best way and under certain conditions the application is painful. The most satisfactory method and the one almost universally used is that of the shunt resistance.

A diagram of this arrangement is shown in figure 17.

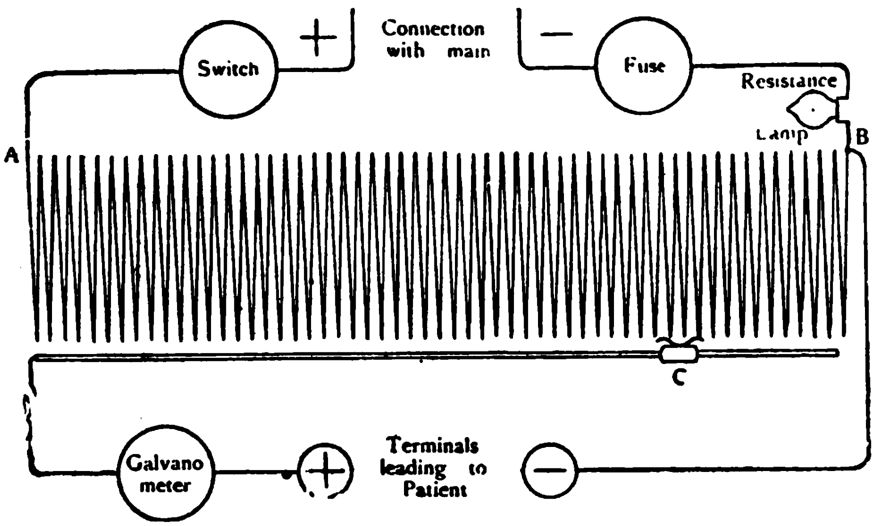


Fig. 17. Plan of Shunt resistance

If we trace out the connections we see that the current comes in from the main at the positive terminal to the switch. When the switch is turned on the current flows through the fine resistance wire from A to B, then through a lamp and safety fuse to the negative terminal of the main. We have here what is called a slope of potential form A to B with a further fall through the lamp at B. This fall on a 100 volt circuit would be from 100 volts at A to zero at the — side of the lamp at B. The lamp regulates the amount of current that can be allowed to pass, protecting the resistance from over-heating and is also useful to show when the instrument is connected with the main as the lamp continues to glow whether the electrodes are in contact with the patient or not. If we take a sensitive voltmeter and connect one terminal to B, and having attached a piece of wire to the other terminal of the voltmeter draw the free end of this wire across the turns of the resistance from B to A, we will find we can get any voltage we desire from zero up to the highest given by the instrument—this will be from 50 to 80 depending on the resistance of the lamp at B.

To take advantage of this there is provided a slider C movable on a rod which is placed parallel to the resistance, and at such a distance that the springs of the slider C are always in contact with it. For use we take a wire from B and one from the rod upon which the slider moves. In series with one of these is placed the galvanometer. The slider is always kept to the right when there will be found to be no difference of potential between the terminals leading to the patient. As we move the slider along the difference of potential rises until the galvanometer shows we are passing the desired amount of current.

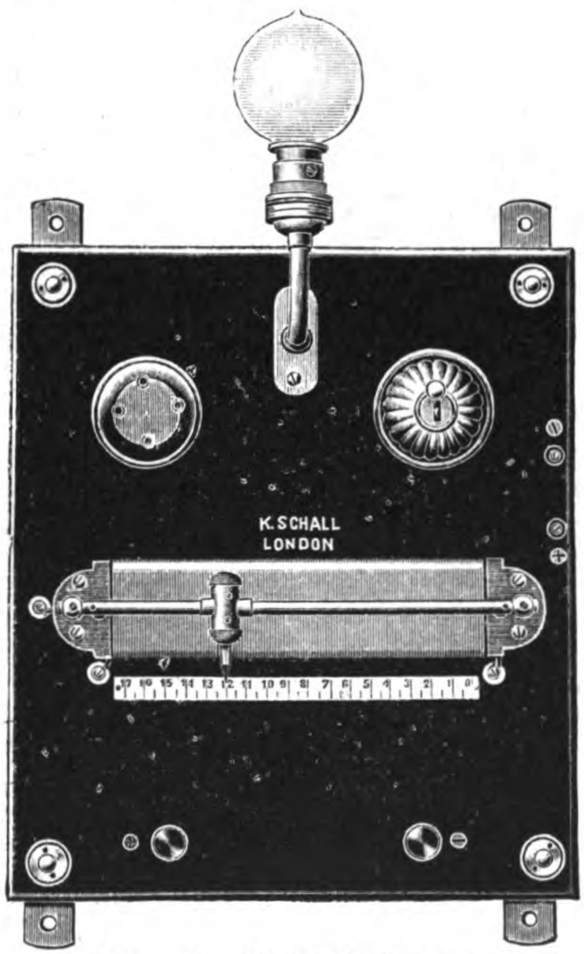


Fig. 18. Shunt Resistance.

Figure 18 shows a simple form of the instrument. Several of these, fitted with galvanometers are in constant use in the Electrical Department of the London Hospital and are entirely satisfactory. These boards are there arranged that either constant or sinusoidal current may be supplied to any one of them at will. Another form is shown in figure 19, where an induction coil is provided,

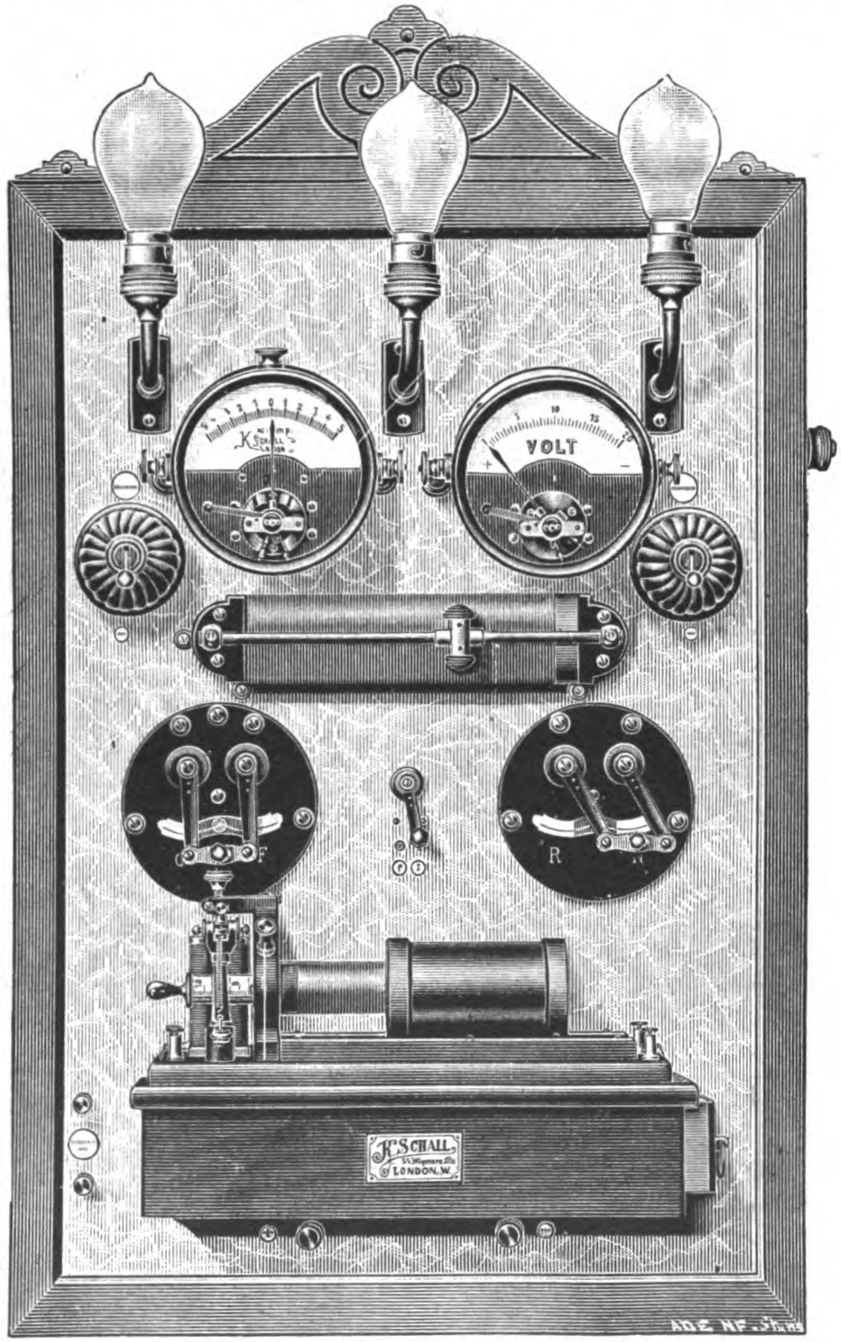


Fig. 19. Galvano-faradic outfit.

making a complete galvano-faradic outfit and one which is in very general use.

The voltmeter is not essential but it is very convenient to have. It shows the difference if potential between the electrodes applied to the patient, and by its use rough approximations of the resistance between the electrodes can be arrived at by taking the reading in volts and milliamperes and working it out by Ohm's law.

The electrodes are attached to the terminals at the bottom of the board, and by moving the handle, just below the left end of the shunt resistance, galvanic or faradic current is supplied to them.

This apparatus may be used for diagnosis, treatment, electrolysis, and for lighting small lamps. In the last case the milliamperemeter should be cut out for fear of its being injured by over-heating. This is provided for by means of the small knob seen at the top of its case. Turning this knob brings some figures behind an opening in the dial just above the centre of the scale. These are usually 1, 10, 100, and 0. When the last is showing it means the instrument is cut out. The use of the other figures will be explained more particularly when describing measuring instruments.

It would of course be out of the question to use this instrument for heating a cautery, as the amount of current required is about one hundred times greater than the instrument would carry without injury.

If it is required to heat a cautery only occasionially, a shunt resistance made on the same principle will do. It is not very expensive, but while in use is very wasteful of current, on this account a signal lamp is provided to show the operator when the current is on so that it may be turned off the moment it is no longer required. In the diagram, Fig. 20, a small rheostat is shown in series with one of the terminals. This gives a finer degree of regulation than is obtainable by means of the slider alone. A resistance in series will not do for anything above 25 volts. The reason is that a series resistance, while preventing the amount of current exceeding a certain limit has no effect in keeping down the voltage. The moment we attempt to break the circuit with the key in the cautery handle the full pressure of the mains at once asserts itself and keeps the current flowing across the gap in the form of a flaming arc. This arc would destroy any cautery handle in a few seconds.

Wasteful as the shunt resistance is for cautery and spark coils for X-ray work, on any pressure up to 100 volts, it is infinitely more convenient and satisfactory than is the use of primary batteries, and as it will be required only occa-

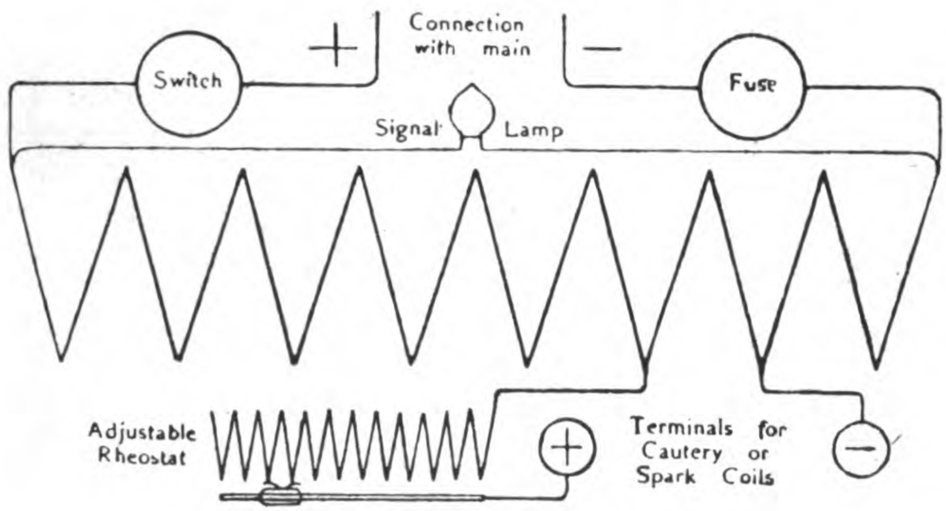


Fig. 20. Shunt resistance for Cautery.

sionally in most instances, the cost for electricity will be so small as to be unworthy of serious consideration. On account of the large amount of current required extra heavy mains and fuses must be provided to carry it safely. Where current for cautery or spark coils will be required very frequently and especially where the voltage of the main current is 200 volts or more it will be found much more economical to use what is called a motor transformer or motor generator.

Motor generator.—As its name implies, this is a combination of an electric motor and a dynamo or generator. It may consist of two separate machines joined together, end to end on one base or they may be combined in one machine. The efficiency of the latter arrangement is perhaps not quite so high as with the other, but it is cheaper, less bulky, and has fewer parts to maintain. The armature of the machine is wound with a long fine wire the length and diameter of which are chosen according to the e.m.f. of the supply and the capacity of the machine. The current causes the armature to revolve as a motor. Next a shorter and a stouter wire is wound over the first winding, and this rotating in the same magnetic field generates a current lower in voltage but of greater magnitude which is collected from a separate commutator placed at the opposite end of the armature. It may be connected direct to spark coil or cautery, and also used for charging accumulators.

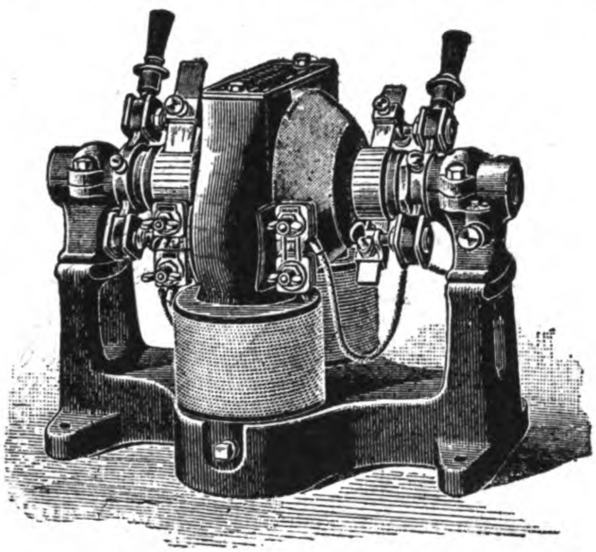


Fig. 21. Motor Generator.

These machines which are sometimes called continuous current transformers can only transform from one fixed voltage to another fixed voltage, and the smaller sizes will only return from 40 °/。 to 60 °/。 of the energy put into them.

They are thus much less efficient than the alternating current transformer which latter can also be arranged to give any desired voltage at will. The motor generator, however, is the best device we have for transforming continuous current, and where the amount of current required is large it will be found both economical and satisfactory. When ordering a machine of this kind to be used for general medical work, one should provide for two or more slip rings on the armature shaft, connected with proper points in the armature low voltage winding. This will enable one to obtain sinusoidal current which as we will see later on is very desirable. The author has a machine with no less than six of these rings in addition to the usual commutator. From it single phase, two-phase or three-phase currents can be obtained at will. This arrangement has been found very useful for both practical and experimental purposes.

Another method of utilising the high pressure direct current mains is to charge an accumulator therefrom through a resistance and then use the accumulator independently. This system has many advantages for certain purposes. It enables one to keep a battery charged which can be taken about and used for cautery, light, or working a X-ray coil. With the direct current laid on the charging of a battery is most simple. A special plug is provided which is fitted with a lamp holder so that lamps of different resistance may be used. From this plug runs a double flexible conductor. Having ascertained which one of these is positive it should be marked so as to avoid confusion in the future. This end must always be connected to the + terminal of the battery and the other one to the − terminal. A 16 c.p. lamp should be placed in the lamp-holder and the plug inserted. The accumulator may be connected up to the main when the day's work is done and left going all night when sufficient energy will have been stored up to last one or more days according to the demand made upon it.

As the resistance lamp used glows with almost its full candle power there is no reason why it should not be arranged to take the place of one of the lights regularily used in the house. In this way the charging of the accumulator costs practically nothing.

Alternating Current—As has been shewn before, the great advantage of the alternating current is the ease with which fresh alternating currents can be produced of any desired voltage, by the use of transformers. The alternating current answers equally well for both light and cautery, and the cost of running these is, thanks to the high efficiency of the transformer, almost infinitesimal. Of course shunt resistances may be employed just as for direct current if desired, but such a method is crude, wasteful and unscientific, when we consider how much better means we have at our disposal.

Transformers for medical purposes are generally arranged to give two or three different voltages which are nearest to what is likely to be wanted the final regulation being effected by sliding resistances.

Figure 22. shews an arrangement of this kind which has a very extended use.

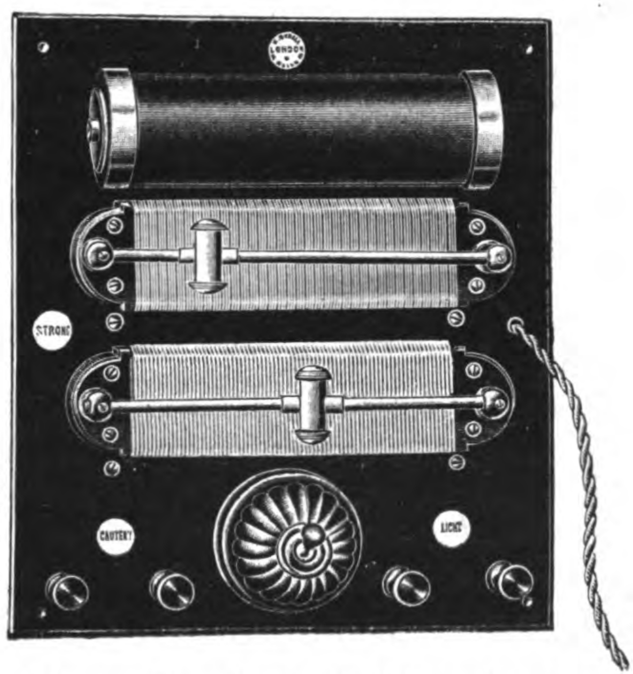


Fig. 22. Transformer for light and cautery.

In some ways the Woake's Transformer is most convenient. It has three secondary windings, and the regulation is effected by sliding the secondaries over the primary winding and core which is common to all.

One secondary is of thick wire and gives a current of about four volts for cautery, the second is of finer wire and gives a maximum voltage of about 15 for lighting small lamps, and the third is of still finer wire for electro-therapeutic purposes.

Each secondary has its own pair of terminals. It is not very efficient electrically as compared to transformers with a closed iron core, but it permits of excellent regulation which is a great advantage.

For those purposes, for which an alternating current is unsuitable, some means must be adopted to obtain direct current from alternating current. There are three principal methods of doing this :—

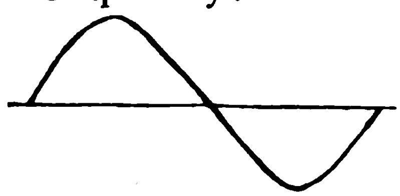
(1) A combination of an alternating current motor with a direct current dynamo. This arrangement is quite satisfactory and nearly as efficient as the direct current transformer. We can of course have any voltage and amperage choose up to the limit of the capacity of the a.c. Motor.

(2) By means of a rotary converter. This is an ordinary direct current motor which has a pair of slip rings in addition to the commutator. The rings are connected one to each of diametrically opposite segments of the commutator. They are of course provided with collecting brushes. The machine must have at least four poles instead of the usual two-pole arrangement.

It has first to be speeded up to what is called synchronism. This means that speed which when it is acting as a dynamo, the alternating current in its armature will have the same frequency or periodicity as the alternating current of the main we are going to use. When this speed is reached the alternating current is turned on to the slip rings. The machine will now run as a synchronous motor and direct current may be taken from the brushes bearing on the commutator. These machines in the small sizes are not altogether satisfactory. They are very sensitive to small changes of load and once they get out of synchronism they very quickly stop. It seems that the high periodicity of the a.c. mains is partly responsible. This varies from 40 cycles to 100 cycles per second. Rotary converters do much better on lower periodicities of about 25 per second. While electrical engineers have shown a tendency to lower their periodicities during recent years, they have not as yet got so low as 25 periods in this country. The supply from the famous power station at Niagara is 25 to 30 periods, as are also several large electrical undertakings on the continent.

The third method of obtaining direct from alternating current is by the use of rectifiers. To describe these interesting devices in full is beyond the scope of a work of this size. The most that any rectifier can do is to change an alternating current into an uni-directional current. It is not a continuous flow, but consists of distinct impulses, all of which flow in the same direction. If we describe the alternating as a vibratory current, the rectifier renders it pulsating.

Graphically :—instead of



we have

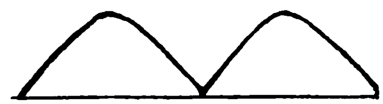


Fig. 23.

Rectifiers are of two kinds. Chemical and mechanical.

Chemical rectifiers depend for their action on the peculiar property of aluminium in that it offers a very high resistance to the passage of a current when it is made the anode of an electrolytic cell, at the same time it offers no particular resistance when it becomes the cathode. By means of a small cell of this kind an accumulator can be charged direct from the alternating main and left going all night, and in that way the battery kept charged and always ready for use. It is impossible for them to get out of order under ordinary circumstances and are quite independent of any temporary interruption of the main current. They are made of various sizes, the larger of which can be used to run large spark coils and drive direct current motors, as well as for charging accumulators. What is known as the Nodon Valve is a rectifier on this principle. The weak point of these rectifiers is that they are messy contrivances, and on account of the heating of the electrolyte have to be made very bulky when currents of any magnitude are passed through them.

Of mechanical rectifiers there are two forms, the vibratory and the rotary. The rectifier of Dr. Batten is an example of the first. In this a steel rod magnetically polarised, is caused to vibrate between the poles of an electro-magnet fed by the alternating current. The rod vibrates in synchronism with the alternating current, and in its excursion makes contact with two studs alternately It is very useful where small currents only are required and where it is not working against a high counter electromotive force. In the latter case arcing at the contacts is a likely source of trouble.

The rectifier of Siemens Bros. is of the same type but on a larger scale and capable of dealing with large currents.

Rotary rectifiers consist of a commutator fixed on the shaft of a synchronous motor. The author spent some considerable time in evolving a satisfactory machine of this type. His first machines, though giving good results in his hands, were not altogether satisfactory. In the first place they had to be brought to synchronous speed by some means before the alternating current was turned on, and secondly they were too sensitive to sudden changes of load and to disturbances of the main current. The later machines overcame the first difficulty entirely, and the second as far as it seems possible to do in the present state of our knowledge. It is an adaptation of the Ferranti Rectifier, which is in use in many electric lighting stations in this and other countries. The motor is quite self-starting, reaching synchronous speed in a few seconds. It has no tendency to fall out of synchronism so long as the main current is constantly supplied to it. The motor also has its own commutator and is quite independent of the current undergoing rectification. The rectifying commutator is made of large size so as to deal with large currents if desired. This machine is also made with a mercury break attached, so that large X-ray coils may be worked from the alternating current direct; with results not excelled by any other means, provided all adjustments are properly made. One of these machines made by the author in 1901 is still running and in perfect order. When charging accumulators it is frequently left running all night and never has a mishap occurred. They are now made by Newton & Co.

The rectified alternating current can be used for many purposes for which continuous currents are necessary. For charging accumulators some authorities consider it superior to constant current, and as a result of considerable experience the author is inclined to agree with this view. It will drive continuous current motors quite satisfactorily and can be adapted to operate large spark coils so to give excellent results. It is not smooth enough for direct application to patients.

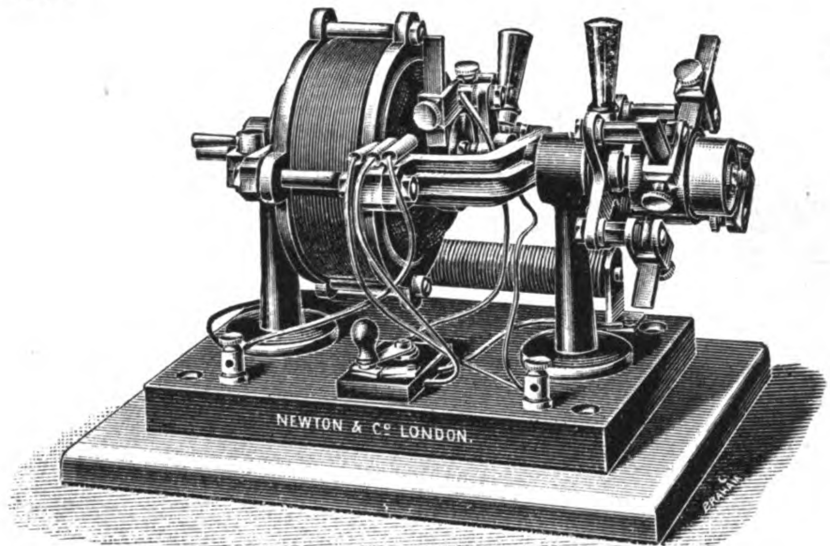


Fig. 24. The Author's Rotary Rectifier.

It has been proposed lately to make use of three-phase alternating currents in therapeutics. The current is obtained from a direct current motor, which has three slip rings mounted on its shaft, and which are connected one to each of three equidistant segments of the commutator. When the motor is running, and electrodes from the three brushes bearing on the rings, joined through a resistance, which may be the human body, the latter is traversed by three alternating currents, where impulses follow each other at an interval of one third of a complete cycle. While the future is full of possibilities, three-phase, or polyphase currents have not come into extented use as yet. Those who wish to enquire into this particular subject should refer to "Polyphase Currents in Electrotherapy," by Dr. G. Herschell.

In all cases where patients are being treated by means of electricity derived from the street mains, there are certain precautions which must be observed to prevent accident.

On account of the high pressures used, it is always possible to give unpleasant, even dangerous shocks. Even if such an accident should not be attended with serious results, it is very disconcerting to all concerned, and patients sometimes strongly resent even slight shocks if they have not been warned beforehand. Carelessness in this respect leads to loss of confidence on the part of the patient and possibly even the loss of the patient. A system of distribution known as the three-wire system, comes from the generating station, in the form of a three wire cable. One of these is the positive, another is negative, and the third is neutral and acts as a common return to the others. The neutral is positive to the negative wire, and negative to the positive wire, and by a rule of the Board of Trade, must be connected to earth. Consumers are supplied from the neutral and one or other of the other two. There is thus always the full pressure of the supply, between one of the terminals and anything that is connected to earth. A patient under treatment should be so disposed that no conductor connected with earth is within reach, such as gas or water pipes, electric light fittings, etc.

Great care should be taken that there are no broken wires anywhere in the apparatus,—the fine wire resistance may give trouble in this way—also see that all connections are well and carefully made and all screws well tightened up. Loose connections are a fruitful source of trouble and may give rise to severe shocks.

Necessary as these precautions are under ordinary circumstances, they become doubly so in the case of the electric bath. Here the patient is quite devoid if any protection which a dry skin or clothing might otherwise afford him, and is also quite unable to help himself quickly when immersed in the water of the bath. At the London Hospital, a porcelain bath is used, a length of rubber pipe separates it electrically from the waste pipe, and the water pipes for filling are well out of reach of the patient while in the bath. This arrangement has worked very satisfactorily.

A bath in an ordinary house, of course, cannot be so arranged. In such a case it is better to obtain the current from a portable battery if constant current is desired, and by means of a transformer if sinusoidal is wanted.

Where current from the main is not available some other source of supply must be resorted to.

If it is intended to use electricity more or less extensively, of course the best way is to install a dynamo and drive it by means of a gas, oil, or steam engine, or even a water turbine if such power is available. The current could be used direct, but it would be found more convenient to charge accumulators and use the current from them. In this way the engine need only be run for a few hours, on two or three days a week, and the current will be available at all times. Where space is a consideration, there seems no valid reason why a very compact little plant could not be designed for the use of a petrol engine such as used on motor bicycles, coupled direct to a dynamo, suitably designed for the purpose. A set to give 15 amperes at 60 volts would meet most medical requirements in a private practice or small hospital and ought to run very satisfactory. Water cooling would have to be substituted for air cooling and perhaps a few minor details would require readjustment. In all cases the dynamo should be provided with slip rings so that alternating current can be obtained when necessary.

While the upkeep of a small private plant as above indicated is not very costly, the initial outlay may prove an unsurmountable obstacle. If there is a place in the neighbourhood where cells can be charged, then accumulators should be used. With the large and increasing demand for facilities for charging ignition batteries for motor bicycles and motor cars, such a place will be easy to find in most instances.

Accumulators.—Secondary Batteries or Storage Batteries as they are often called are the most satisfactory means we possess of obtaining electricity from chemical action. The name "Storage battery" is not correct. We do not store electricity in an accumclator, but if we take a cell that is run down and drive a current through it in the opposite direction to the current it gave out when working, we can restore the plates to their original condition and so give it a new lease of life so to speak—

and so long as we do not charge or discharge the cell at a greater rate than that for which it is designed, this process can be repeated almost indefinitely.

While Edison has lately brought out an accumulator which may prove useful and in which the active materials are nickel peroxide and iron in a solution of caustic potash, at present the lead accumulator is the only one used. The plates consist of a metallic lead grid the spaces of which are filled with a paste made of red lead in the case of positives and litharge for the negatives. The electrolyte is dilute sulphuric acid S. g. 1200. The plates are placed close together and have large area as compared to primary batteries. The internal resistance is exeeedingly low—so low that except for the most accurate observations it need not be considered at all. Each cell gives two volts under ordinary working conditions and continues to do so until about 75°/ₒ of its charge is spent. If the cell be discharged still further the voltage begins to fall. It should never be allowed to fall below 1.8, nor should it ever be left at this latter figure for any length of time—recharging should be resorted to immediately. If this be neglected a white desposit appears on the plates—insoluble sulphate of lead. This increases the internal resistance and diminishes the capacity of the cell and it may be safely stated that a cell which has once become markedly sulphated can never be restored to its original condition. All cells have a certain rate of charge and discharge which depends on the size and capacity and which should never be exceeded. The charging current is usually about 10°/ₒ of the full capacity That is, a sixty ampere hour cell should not be charged with a greater current than 6 amperes. This continued for ten hours, would fully charge the cell.

Accumulators of all sizes and of various makes can now be obtained very readily on account of the demand created by users of motor cars and bicycles.

A dozen 4-volt batteries such as used for motor bicycles could be arranged to meet most medical requirements by means of a multiple switch, which would put them all in parallel, for cautery or light, and all in series for therapeutics—with a shunt resistance. The charging of an accumulator should be continued until the voltage reads to 2.5 volts per cell. The voltage remains at this for a short time only after charging is stopped, when it declines gradually to two volts.

The working voltage of the new Edison Accumulator is 1.33 volts. It seems capable of withstanding a lot of bad treatment--both electrical and mechanical—without suffering very much for it. On this account it may become very popular among medical men who are not as a rule noted for the extreme care they take of their accumulators, or other electrical apparatus.

One great objection to the lead accumulator is its weight,—a battery for running a large spark coil weighing about fifty pounds, but they are no heavier than primary batteries giving the same output per charge.

Primary Batteries.—If for any reason none of the foregoing sources is possible the supply may be obtained from primary batteries. Most electrical students of more or less eminence, have at one time or another devised a primary battery of some kind. A description of all the kinds that have been devised would fill a good sized volume. Only those will be described here which are easily obtainable and easily recharged or renewed when run down or worn out. For applications to patients, electrolysis, or even lighting small lamps for a few minutes at a time there is no cell more satisfactory than the Leclanché. So much are they used for electric bells that they can now be obtained not only from dealers in electrical supplies, but also from most ironmongers and plumbers. The quart-size can be obtained for not more than eighteen pence per cell complete. If a little water is added to each cell occasionally to replace loss by evaporation and they are kept in a cool place they will work well for from one to three years according to the amount of use they receive.

The elements are zinc and carbon. The zinc is in the form of a rod with a wire cast in the top end for connection. The carbon is in the form of a plate and is placed in a small pot of porous earthenware packed full of granulated carbon and peroxide of manganese which acts as a depolariser—slowly oxidising the hydrogen envolved by the cell. If a large current is taken from the cell the hydrogen is not oxidised quickly enough, and after a time the cell becomes polarised. If the circuit is left open for a while the cell completely recovers. Of course after considerable use the depolariser becomes used up and then a fresh porous cell will be required. The exciting fluid is a solution of ammonium chloride, commonly known as sal ammoniac. A saturated soution is frequently advised, but a solution of half the strength seems to work equally well for most purposes and gives less trouble with creeping of the salt over the jar and terminals, leading to corrosion and even destruction of the latter. In setting up a battery of this kind for the consulting room, it is better to have them outside or in some out of the way place. They should then be joined up in series and a wire from each end of the series brought to the operating room and there joined to a shunt resistance as in the case of the current from the main. This method permits of most perfect regulation, uses up the cells equally, and takes up least room. Another method is to use what is called a crank collector. This consists of a metal arm pivoted in the centre of a disc upon which are arranged as many studs as there are cells in the battery. These studs are insulated from each other and arranged in a circle so that the metal arm as it is rotated comes successively into contact with the studs. The cells are all joined up in series but a wire has to be brought from each junction to one of the studs, to which they are joined in regular order. In this arrangement the first cells are always used, those at the other end are used very seldom.

The double collector fig. 25 is an improvement on this, enabling any group of cells to be used at will. It has two cranks mounted on the same axis but insulated from each other. One crank is connected with the positive and the other to the negative terminal. An index is fitted to one ot the cranks which shows at a glance the number of cells in action at any moment. Next to the shunt resistance it is the best method of controlling the current from a battery of this kind.

Dry Cells.—These are used where portability is a prime consideration. They are really modified Leclanche cells in which the exciting fluid is replaced by a moist pasty composition. They tend to run down in from six months to a year whether they are used or not and must

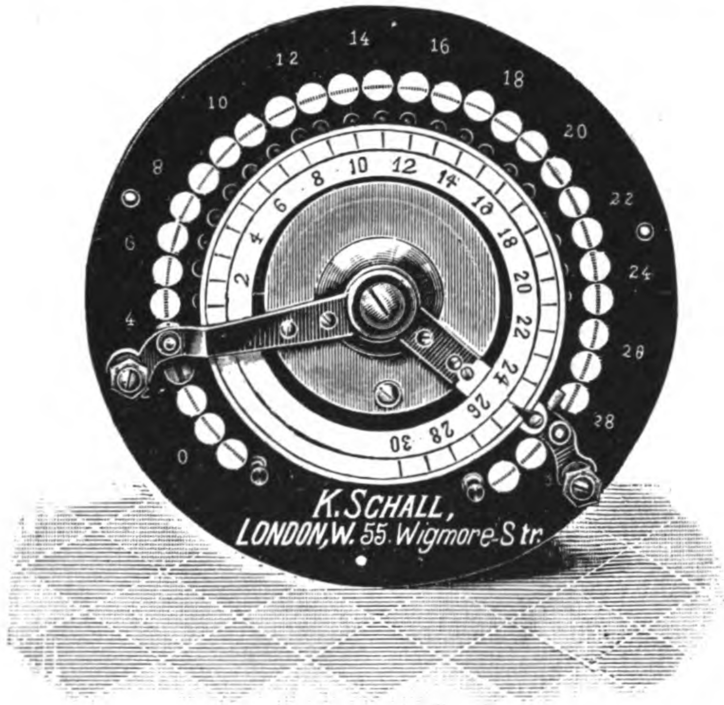


Fig. 25

be replaced by new ones. Some makers allow about 50°/o of the original price for the old cells in exchange for new ones.

These dry cells can be obtained from most electrical dealers.

Leclanché cells have an e.m.f. of about 1·5 volts when new, and their internal resistance is from ·75 to 1·5 ohms—the rule being that the smaller the cell the higher the internal resistance. They are now almost universally used in portable batteries.

For cautery and working large spark coils the bichromate battery is the most easily managed where some form of primary cell must be used. The plates are of zinc and carbon. They should be of large size, placed close together to reduce the internal resistance to its lowest limit, and arranged so that they may be readily removed from the exciting fluid the moment the current is no longer required. The zincs must be kept well amalgamated. The exciting fluid consists of one pound of potassium bichromate dissolved in 8 pounds of hot water. Then add slowly 2½ pounds of strong sulphuric acid, stirring constantly all the time. While still hot dissolve in the mixture 3 ounces of bisulphate of mercury. Each cell when freshly charged has an e.m.f. of 2 volts, but this tends to decline as the cell is used—due to the gradual weakening of the exciting fluid. When this becomes green in colour it should be thrown out and fresh solution put in. These cells should be thoroughly washed and cleaned every three or six months according to size, and care taken to remove all the crystals of chrome alum which will be found sticking to the plates and acid vessel. The zinc plates are dissolved as part of the action of the cell and will eventually have to be replaced. This is not difficult in most forms now obtainable.

CHAPTER III

MEDICAL BATTERIES AND ACCESSORY APPARATUS

THERE are a large number of portable batteries on the market, made up in various styles and sizes. It is desir-

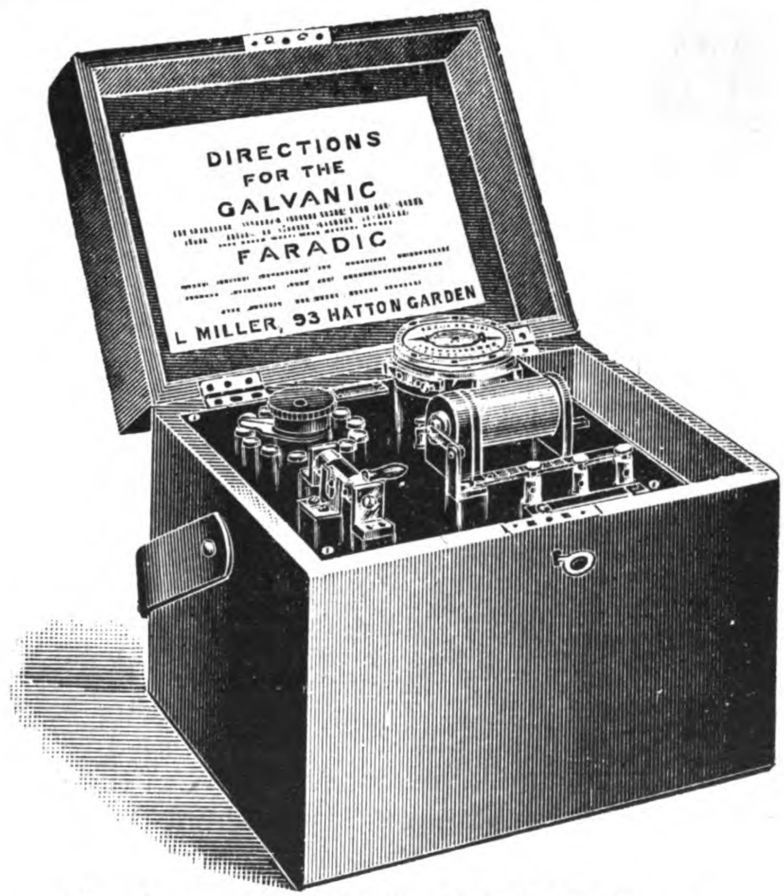


Fig. 26. Portable Combined Medical Battery.

able to have one as light as possible and all the parts must be as small and compact as is consistent with efficiency.

A useful size will contain 30 of the smallest size Leclanché cells, with a collector, current-reverser, milleamperemeter and small induction coil.

One of this kind is shewn in figure 26.

This will be found to answer for testing, treatment by constant or induction coil currents and occasionally for the destruction of naevi by electrolysis. New cells should be put in about once a year, unless they are used very steadily when they will require renewal more often.

Batteries vary so much in detail that it is impossible to give instructions for use. Full directions are always sent out with them by the makers, and a personal explanation is always given if circumstances permit. Some batteries have only one pair of terminals. This necessitates an extra double armed switch to change from the battery current to the coil current. This is unnecessary since by using three terminals—making the middle one common to both—the same result is attained and space economised.

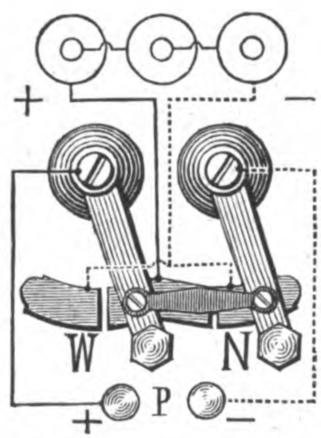


Fig. 27. Reversing Switch.

The current reverser is a simple device for reversing the polarity of the terminals and consequently of the electrodes attached to them. The battery current terminals are always marked + and −, and this means they are positive and negative respectively when the handle of the reversing switch is over towards N (or 'normal') as shewn in fig. 27. When the handle is moved to the left or W—in this country the letter R is used instead, meaning 'reverse'

—the + or positive becomes the – or negative pole, and vice versa. The connections in the figure make this quite clear.

Conducting Cords should be made of insulated flexible copper wire, and provided with suitable tips for securing to the battery terminals and electrodes. From $1\frac{1}{2}$ to 2 yards is a suitable length. They can be easily obtained and are inexpensive. A spare set should always be kept ready. These conductors sometimes break inside the covering—especially near the ends—and may give trouble. If the current fails at any time, it is as well to make sure the fault is not in the cords before obtaining skilled assistance. It is useful to have cords of different colours, such as red and green, and always attach the red one to the positive terminal.

Electrodes.—These are plates, made of some conducting material, of various sizes and shapes by which the current is applied to the patient's body. They may be made of carbon, but metal is more easily kept clean, and is to be preferred. All electrodes must be covered with some absorbent material, such as flannel, wash leather, etc., which can be soaked in water. Bare metal must never be used to apply electricity to the body surface —it not only causes pain, but sets up electrolytic action in the skin, resulting in burns or blisters. In most electrical applications one pole is applied to the affected part—the *active electrode*—while the other pole is applied with a large plate placed on some other part of the body, such as the sternum or along the spine—the *indifferent electrode.*

Indifferent electrodes are of large size—from 10 sq. in. to 100 sq. in. or more—and usually made of lead, tin, or pewter, about $\frac{1}{32}$ in. thick and cut to any shape the requirements of the case or fancy may dictate. A terminal for attaching the conducting wire is soldered on the back, and the whole is enclosed in a bag, the back of which is made of American cloth, and the front of flannel or wash leather. By this arrangement the front surface can be soaked in water and slipped under the patient's clothes without wetting the latter. It should be bent to fit the surface as far as possible and kept in position by gentle pressure.

The patient can generally hold it on the sternum, or if reclining on a couch it can be placed underneath the shoulder blades or hips. The rule is, the longer the application is to be made or the greater the amount of current, the larger the indifferent electrode is to be. The electrode is sometimes embedded in potters' clay, which adapts itself perfectly to the surface. For active electrodes, circular metal discs are the most generally useful. Four sizes, $\frac{1}{2}$ to 3 in. in diameter will meet most requirements. They are made to screw on to a terminal which is mounted on the end of a handle made of wood or ebonite. This

Fig. 28. Electrode Handle.

makes them very convenient to use, and the operator is insulated from the current. Fig. 28. For testing purposes the handle is fitted with a switch or key for closing the circuit. In using it the electrode is first placed on the desired spot, the key is then depressed, and the current

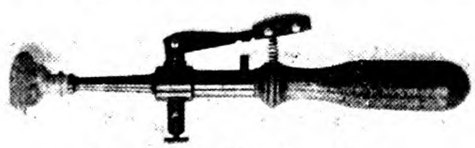


Fig. 29. Closing Key.

flows. A good form of disc is shown in figure 30. It is made with a rim turned back from the face, and

Fig. 30.

provided with a celluloid ring a little larger in size. A piece of flannel or wash leather is placed over the disc, and the ring pushed over both, holding the fabric firmly in place—the superfluous material is then trimmed off with scissors. Recovering a disc is the work of a few seconds, so that there is no excuse for using a cover more than once. In private practice especially, the invariable rule should be to use only new covers, fresh clean towels and warm water for every patient. Neglect of these details will surely lead to loss of patients sooner or later. Some people are extremely fastidious on such matters, which is not in the least unreasonable.

Resistances or Rheostats. — These are appliances for regulating the amount of current flowing through a circuit by increasing or decreasing the total resistance of that circuit. They are particularly useful for controlling the current in lamps and cauteries. At one time they were much used for controlling the currents used in treating patients. Their use for this purpose has for the most part given way to the cell collector or the shunt resistance, which acts by varying the electromotive force. Resistances have to be made according to the work they have to do. For cautery and light they are made of a

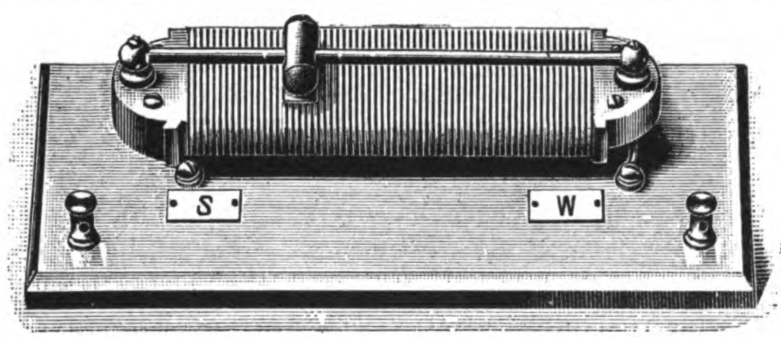


Fig. 31.

comparatively few turns of coarse resistance wire wound on a bar of slate, and provided with a slider by which more or less of the turns are thrown into circuit. The total resistance of such a rheostat will vary according to the work for which it is intended—from 30 ohms for surgical lamps to one ohm in the case of cautery burners working from a battery, or heavy shunt resistance across the street mains, as shown in the previous chapter. Speaking generally, the total resistance of a rheostat should be about equal to the resistance of the circuit it is to control.

Such an one as here described would have no appreciable effect if placed in circuit with a patient, whose resistance may be many thousands of ohms. A rheostat for this purpose should have a total resistance of from 1000 ohms too 100,000 ohms or more, according to the voltage of the supply, and so made that the resistance can be varied gradually and without any jumps. Very useful instruments are made of graphite for this purpose, and have the merit of cheapness. One is shown in plan in Fig. 32. As the

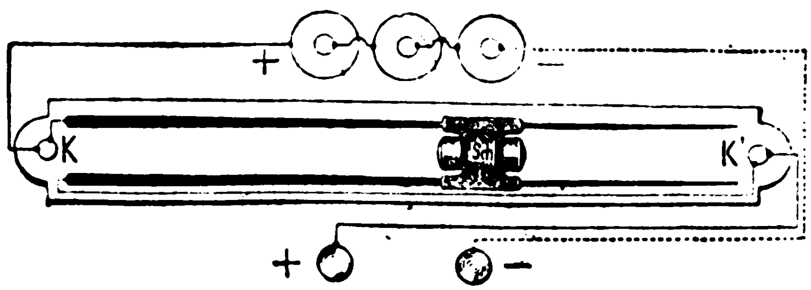


Fig. 32. Plan of graphite resistance.

slide, which touches both graphite rods, is moved to the right, the resistance increases, and vice versa.

The water rheostat is simple and also cheap. It consists of a glass tube, the lower end of which is closed with a piece of platinum, which acts as one electrode. The second electrode is a piece of zinc which may be moved up and down in the glass tube. If the tube is filled with some badly conducting liquid, and the zinc drawn up to the top, the resistance is greatest, and becomes less as it is moved down towards the platinum. With currents of any magnitude the electrodes become covered with minute bubbles of gas, and the resistance thus is being continually altered. For this reason their use will always be limited.

Rheostats have been made and used in a multitude of forms, especially in America, but as they are being displaced by other and better methods of regulation, as already indicated, it is not worth while to take up further time and space in describing them.

For some purposes of treatment it is of value to have some method of varying the strength of the current rythmically. If we, by any means, cause the upper electrode of the water rheostat just described to travel up and down the tube in a regular manner, this result is attained. An average speed would be about two seconds for the whole journey up and down. Clockwork is the simplest form of motor power and most generally used. The polarisation of the electrodes does not give trouble here on account of the commotion in the tube setting the bubbles free. This is very useful in treating wasted or atrophied muscles. It acts as a sort of physiological massage. The slow variation of the current has a tonic effect on the muscle fibres and stimulates their nutrition.

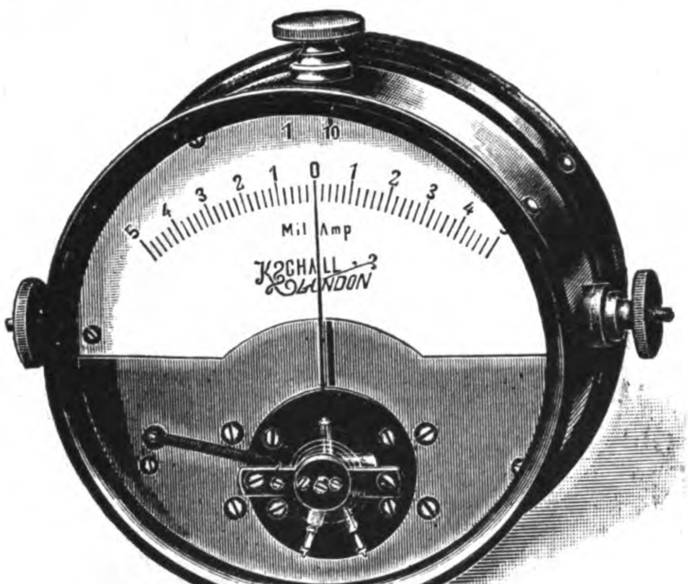


FIG. 33. Milliamperemetre moving coil type.

Measuring Instruments.—Until comparatively recently, all galvanometers and milleamperemeters were of the magnetic needle type. While undoubtedly accurate they laboured under certain disadvantages. They had to be carefully levelled, and placed in proper relation to the magnetic meridian to bring the pointer to zero. The latter always took some time to come to rest, and the readings were easily disturbed by the presence of magnetic bodies near by. It is not necessary to refer to them further as they are being displaced by instruments of the moving coil type, one of which is shown in figure 33.

They read accurately in any position, are quite independent of the earth's magnetism, or the presence of magnetic bodies, and they are "dead beat," that is to say, the pointer indicates the amount of current passing instantly, without first swinging to and fro for some time. The instrument shewn reads to five milleamperes by fifths. As this is too small for some purposes, it is provided with one or more shunts, which can be switched on or off as desired. The principle of the shunt is that when a current has two paths in which to flow, it divides itself between the two, so that the current strength in each path is inversely proportional to its resistance. The arrangement is shewn diagramatically in figure 34.

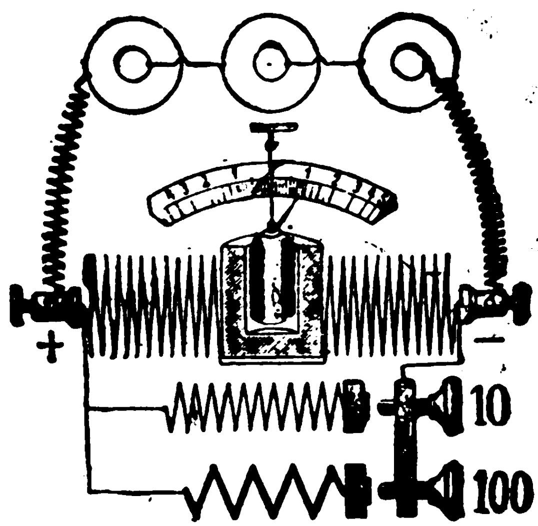


Fig. 34. Arrangement of Shunts to Milleamperemetre

As there shewn, all the current will flow through the coil which causes the needle to decline. The resistance of the shunt marked 10 is so adjusted that when it is brought into circuit $\frac{9}{10}$ of the total current passes through it, and $\frac{1}{10}$ through the coil controlling the needle. Therefore the total current passing will be ten times that indicated by the instrument. If the other shunt is used the readings are to be multiplied by 100. The knob on the top of fig. 33 is for switching the shunts in or out of circuit. As it is revolved, the figure 1, 10, 100, and 0 pass in succession behind a small opening in the top of the dial, indicating which shunt is in circuit. When the zero is shewing, it means the whole instrument is out of action. In this position it is impossible for the instrument to be injured by the accidental passage of a heavy current through it, which would probably cause serious, if not irreparable, damage. Shunted instruments are very little more expensive than plain ones, and should always be selected when buying an outfit.

CHAPTER IV

THE CONSTANT CURRENT AND ITS MODIFICATIONS

THE student has already been warned against the idea that there is more than one kind of electricity. If he visits the electrical department of a large hospital he perhaps sees a patient being treated with the Static head breeze. Another is having the effluve from a high frequency apparatus directed on to some diseased part. Yet another will be seen applying an electrode from a battery, or some source of constant current, over one side of the face for neuralgia, or it may be for facial paralysis. These various methods of applying electricity are so dissimilar to all outward appearance, that it is not easy at first to realise that the currents obtained are all modifications of the same thing, and can all be derived, directly or indirectly, from a common source—that is to say, the constant, continuous, or galvanic current.

In this chapter it is proposed to describe the various forms of electricity, used in medicine, taking this constant current as a starting point.

In all the modifications of the continuous current, the voltage or pressure is more or less continually varying. While this has been known practically since the discovery of electro magnetic induction by Farady, yet our ideas as to the exact character of these variations was somewhat crude so long as we were without some means of accurately recording them. The latest and best instrument for this purpose is known as the oscillograph. It is in fact the sphygmograph of the electrician. So far as sensitiveness is concerned, the latter is a very coarse instrument, as compared to the oscillograph, which is capable of recording fluctuations of such brief duration as ·0001 second. Instead of a needle and smoked paper, it records by means of a beam of light playing on a moving photographic film. As this movement of the recording surface is known and constant, it is easy to ascertain the duration of the impulses recorded. Along the middle of the strip bearing the tracing is a straight line from end to end. This is the zero line, or line of no pressure.

In that part of the tracing which is above the line, the current is flowing in the opposite direction to that which is represented by so much of the tracing as is below the line —and the further the curve is from the zero line at any moment, the greater is the pressure of the current at that moment.

A simple oscillograph tracing is here shown. It represents a current continually varying in pressure, and periodically alternating its direction of flow.

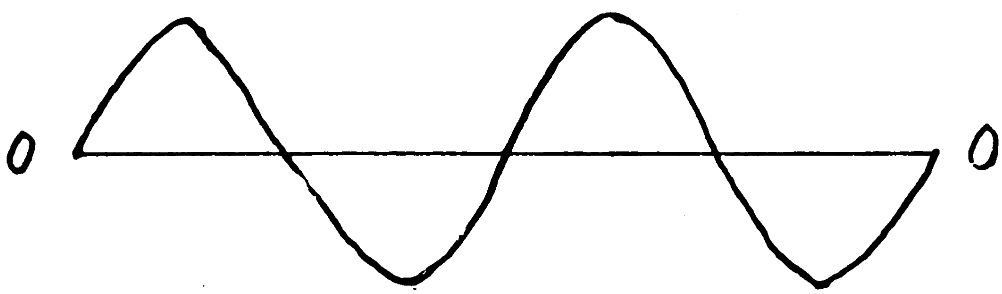


Fig. 35.

To interpret such a tracing, imagine we have it on a long strip of paper. Place the strip with its zero line at right angles to a straight wire which we will suppose to have been traversed by the current already traced on the strip. Now draw the strip slowly across the wire, keeping the eye fixed on that part of the strip which is immediately over the wire. Remembering what has been said above, it will be easy to follow in one's mind the series of changes which took place when the record was made. The student is advised to familiarise himself with the tracings given in this chapter. They are the only accurate means of recording and communicating the features of varying electric currents, and the study of them in connection with certain phenomena has given us knowledge not obtainable by any other means.

The Constant Current.—This is the current we obtain from chemical action, such as takes place in a battery cell. It can also be obtained from a constant or continuous current dynamo. In a closed circuit it flows evenly and steadily, always in one direction, from the positive to the negative pole, and on this account it is capable of the most accurate measurement, a tracing of this current would be represented by a single straight line parallel to the zero line of the strip. This line would be above or below the latter, according to the direction of the current, and the width of the space between the lines would be in proportion to its pressure.

For medical purposes this is probably the most important and generally useful form of electricity we have. The different methods of obtaining it have already been given, while its actions and uses will be set forth in a subsequent chapter. Electricity is perhaps the most flexible form of energy known, and it will be found possible to modify it in many ways and so obtain varying and even surprising effects.

We can modify a constant current by purely mechanical means, or by methods based on the principles of electromagnetic induction which have been already explained.

Simple Interrupted Current—The simplest method of modifying a continuous current is that of making and breaking the circuit so that the latter is traversed, not by a continuous, but by an interrupted current. This can be done by simply bringing the two wires from the battery together and then separating them, or if it is required for some time one wire would be joined to a metallic spring and the other to the axle of a toothed wheel. If the wheel is revolved and the spring made to bear lightly on its periphery the circuit will be traversed with a *simple interrupted current.* The rapidity of the interruptions will depend on the number of teeth on the wheel and the speed at which it is revolved. In practice the spaces between the teeth are filled with hard rubber or other insulating material thus ensuring smooth and silent running.

A tracing of such a current would be represented by a series of short straight lines running parallel to the zero line, with a faint transverse line joining both ends of each one of the series to the zero line. These transverse lines are not quite at right angles to the latter on account of the movement of the recording surface.

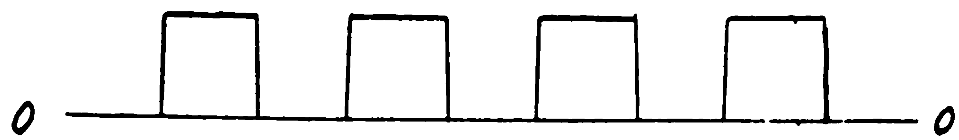


Fig. 36.

Other methods of interrupting the current will suggest themselves. It would be impossible in a work of this size to describe all the varions devices in use for this and other purposes and no more than sufficient to illustrate the principle involved will be given. Further details can be obtained from the larger works on the subject and also from the instrument makers catalogues.

This simple interrupted current is not much used. It will set up tetanic contraction in a normal muscle when applied to its motor point but the application is attended with pain if kept up for more than a second or two. The current, when it flows, is always in the same direction, and consequently the cumulative effect is the same as with the continuous current. Electrolytic products accumulate in the skin in the immediate vicinity of the electrodes—these are chemical substances which irritate the sensory nerves.

The greater the rapidity of interruption the more closely does it resemble the constant current in its action on living tissues.

Simple Alternating Current—The production of this current requires a somewhat less simple device. It can be most easily explained by the use of a Rhumkorffs commutator which is provided on most large induction coils and many medical batteries. It consists of a cylinder of hard rubber A mounted on a spindle B so as to revolve freely. On each end of the cylinder are fixed metal bands C and D and from one side of each band the metal extends for about $\frac{2}{3}$ the length of the cylinder in the form of cheeks C′ and D′ but not so far as to come into contact with the band at the opposite end. The cheeks C′ and D′ are usually made to embrace about one-fourth the circumference of the cylinder and are so fixed as to be exactly opposite each other. Four metal springs are now required. A pair E.E. is mounted one at each end of the cylinder so as to press on the metal bands C and D. The

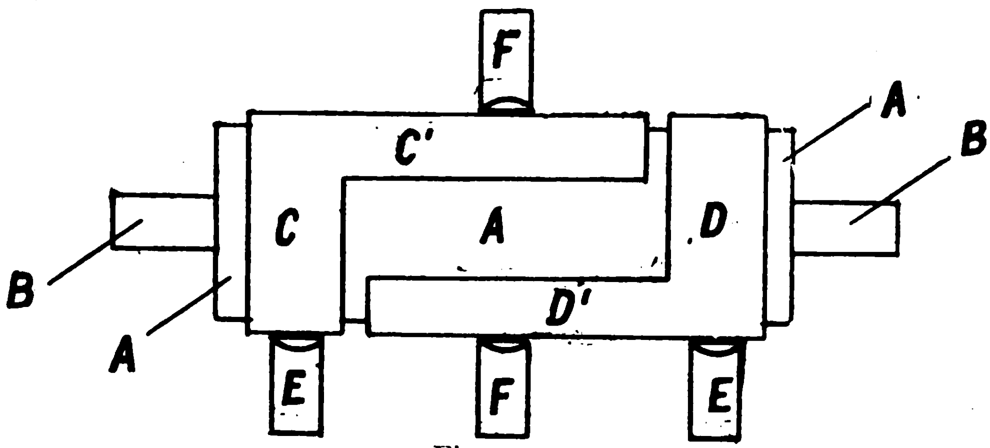


Fig. 37.

other two FF are mounted on opposite sides of the cylinder at its middle so as to touch the cheeks C′ and D′ as the cylinder is revolved. The wires from the battery or other source of constant current are connected to the springs E.E. and the current led off by wires joined to the springs F.F. It will be seen that the direction of flow of current in a wire joining the springs F.F. will be reversed each time the cylinder is rotated through half a revolution, and if the rotation is kept up the wire will be traversed by a simple alternating current. A tracing of such a current would be something like this:—

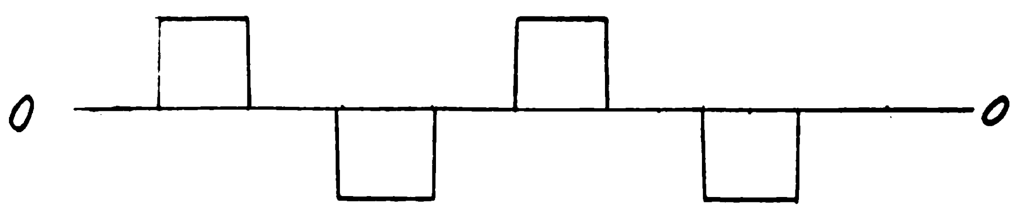


Fig. 38.

In this case the space between the metal cheeks is equal to the width of the cheeks themselves, and consequently each impulse is followed by an equal period of rest. This period of rest can be increased or diminished by varying the width of the metal cheeks. A commutator for practical use is made so as to give from four to eight or more cycles per revolution, and so obviate the necessity for driving it at very high speed. The principle of its construction is the same as the one here described. This current is a most useful one for testing and for some forms of treatment. The impulses being in alternate directions all electrolytic action is neutralised and consequently the sensory nerves are not irritated by chemical products.

A painless current for testing is much to be desired, and it is found that such a current can be obtained, from experiments carried out by Drs. Head, Lewis Jones, and the author. For a current to be without effect on the nerves of pain sense it is essential that the impulses should be alternating in direction, and should give a symetrical tracing—that is, the impulses in one direction must not be longer than the impulses in the other direction, otherwise electrolytic products will be liberated and sooner or later cause pain. Further it is essential that the impulses should follow one another at a certain minimum rate.

As a result of the extremely important and exhaustive investigations by Dr. Henry Head, the evidence goes to shew that such sensations as, pain, touch, temperature are transmitted to the brain by separate sets of nerve fibres. Those which convey to us the sensation of pain are the most lowly organized and are incapable of responding to separate impulses, when these impulses exceed a certain rate. The critical speed below which pain would be felt, and above which it would not, has not been exactly determined, and probably would be found to vary in different individuals. But it has been found a simple matter to construct a commutator and to drive it at such a speed as to give a practically painless current which is strong enough to set up a tetanic contraction in a normal superficial muscle. Further investigation shows that the impulses must be short as well as rapid, and that when each impulse is followed by a period of rest of at least equal duration, before the advent of the next impulse in the opposite direction, the result is more pleasing than when the impulses follow one another without any interval. The use of such a current for testing and therapeutics is a great advantage when dealing with children and highly sensitive individuals, and it is very likely to displace the induction coil to a considerable extent. It has the further advantage that the amount of current used can be accurately measured. Only such current as passes through the patient is affected by the commutator, and consequently if the current going to the commutator is made to pass through an ordinary milliamperemeter—it will be accurately measured by the latter.

On account of the manifest advantages of this current the author has fitted up the table shown in figure 39 which is worked from the continuous current main. The wires from the sliding shunt resistance are taken up to the brushes bearing on the two ends of the commutator, the milliamperemeter is included in the circuit of one of them. The commutator ends consist of plain copper rings. The central part is larger in diameter and is divided into sixteen equal segments, which are carefully insulated from each other and secured to the hub which is of hard rubber. Four equidistant segments are electrically connected to the copper ring at one end, four others midway between these are connected to the other ring. This leaves every alternate segment idle or "dead" as it is called. Two brushes bear on this middle part, and are so arranged that when one is coming into contact with a segment connected with the ring at one end the other bears the same relation to the segment connected to the other ring. The commutator is mounted on the shaft of a small electric motor by which it is driven at a speed of from thirty to forty revolutions per second which answers very well.

With the motor the rest of the current flows straight through without being altered or modified in any way, and to reverse the current in the patients circuit, the commutator is revolved one-eighth of a revolution with a touch of the finger. By means of marks on the commutator one can tell at a glance which is the positive and which the negative terminal. When the alternating current is required the current is switched on to the motor. One

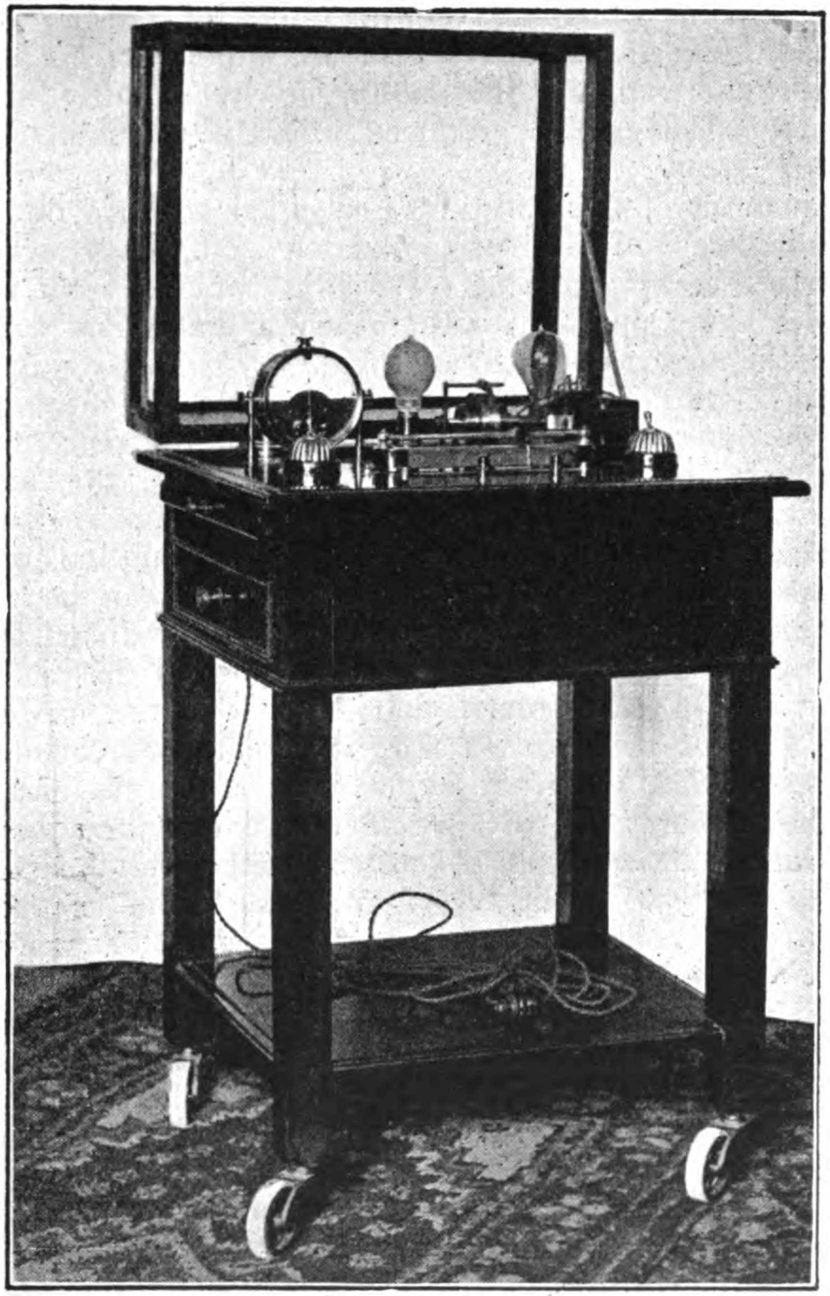


Fig. 39. Consulting room table outfit arranged to give constant and simple alternating current.

of the brushes is adjustable round an arc whose centre coincides with that of the motor shaft. By shifting it backwards or forwards the periods of rest are lengthened at the expense of the periods of contact, which is an assistance in obtaining the minimum of sensory effect. By adjusting the brush to give an impulse of maximum length and running the motor slowly, a fairly intense sensory effect can be produced which is useful in testing sensory areas.

An outfit of this kind is a decided advance on these usually supplied with an induction coil. For portable batteries an arrangement of driving by clockwork would answer every purpose, since the commutator and brushes could be made very small and light.

These two modifications of the constant current, the simple interrupted, and simple alternating currents are the only possible ones without invoking the aid of inductive action. It is of course understood that in making the wheel or commutator the duration of the impulses, and these of rest or no impulse, can be varied within the widest limits and the current produced is still a simple interrupted or simple alternating as the case may be. It is also of course understood that the use of resistences, or rheostats as they are sometimes called, and volt-regulators, does not in any way alter the character of the current. These are merely convenient methods of regulating the strength of current applied to the patient —the principle being very much the same as that of a tap for controlling the flow of water or gas in a pipe.

All the other modifications of the current are obtainable only through methods based on the principles of electromagnetic induction. It will be convenient here to describe the induction coil from which is obtained, the self-induction current and the secondary induced current.

The Induction Coil is probably the best known electrical device in use by medical men and others. It is very inexpensive, especially in its simplest forms and for stimulating living tissues is quite efficient. From the fact that it lends itself very readily to great variation in constructional detail, without seriously interfering with its working qualities, few instruments have been subjected to such extensive modifications—and though much ingenuity has been expended on it, it is doubtful if any substantial improvement has resulted.

Notwithstanding its complicated appearance, especially to the uninitiated, the induction coil is really a very simple appliance. Its essential parts are shewn in fig. 40.

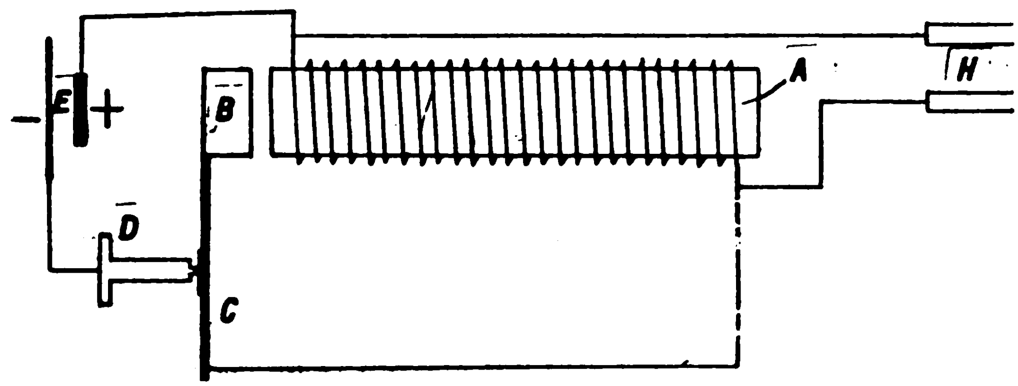


Fig. 40.

A is an iron core—usually made up of a bundle of soft iron wires—around which is wound a comparatively few turns of fairly coarse wire, this is the *primary coil*—in all cases the wire used for winding coils is covered with silk or cotton for purposes of insulation—opposite one end of the core is an iron block B which is secured to the end of a metal spring C. A screw D is mounted so that its point comes opposite about the middle of the metal spring. The end of the screw and that part of the spring with which it comes into contact are both faced with platinum. One end of the primary coil is connected with one pole of the battery E,—the other end is connected to the spring C. The other pole of the battery is connected to the screw D. The course of the current can be easily traced from the battery to the primary coil, from this to the spring C, thence through the platinum contacts to the screw D and so back to the battery. The current passing round the primary coil, the latter becomes with the iron core an electro-magnet. It thus attracts the iron block B and in drawing the latter towards itself pulls the spring C away from the point of the screw D. Immediately this happens the circuit is broken and the flow of current from the battery ceases. The core thus loses its magnetism and the iron block no longer attracted, the spring C by its own elasticity flies back until it is stopped by the point of the screw D. The circuit is thus again closed and the above changes are repeated.

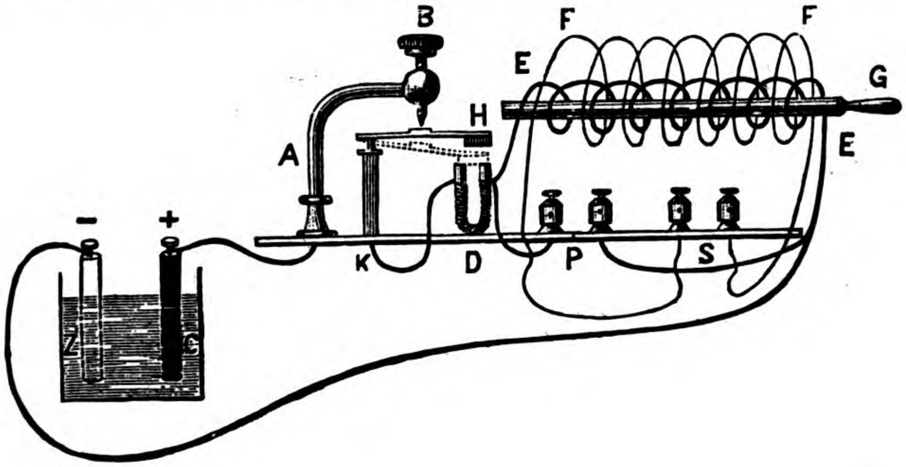
Were it not for the peculiar properties possessed by the primary coil and the iron core, the whole circuit would be traversed by a simple interrupted current. Most medical coils will work with a single dry cell—but if we try interrupting the current of a single cell we will find it impossible to make it give any perceptible shock. But if we grasp in our hands the metal handles H which are connected, one to each end of the primary coil, a more or less strong intermittent current will be felt. This is the current of self-induction. The principles of self-induction have been given in the first chapter and need not be repeated here. It has also been called the "primary interrupted current," "primary induced current," and "extra current."

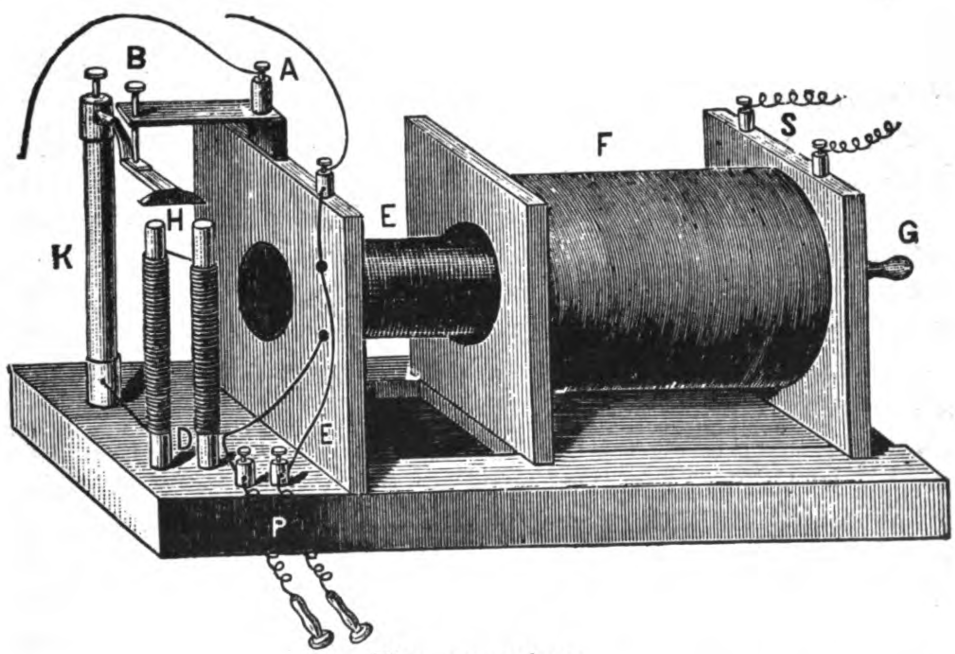
The arrangement of the simple coil above shown does not provide any means of regulation, and the self-induction current from even a small coil is too powerful for most people to bear with comfort, unless it is brought under control in some way.

This need for regulation of the strength of the current has given rise to many of the modifications to which the induction coil has been subjected.

Probably the best way of varying the strength of the current is by inserting or withdrawing the iron core. This of course cannot be done in the above instance as the core is necessary for the action of the interrupter or contact-breaker. This difficulty is got over usually by providing a separate small magnet whose sole duty is to operate the break. The following two figures show the essential features of a modern medical induction coil.

The primary circuit is essentially the same as in the figure previously given except that the current goes through a small magnet D before it reaches the primary coil. The iron core G can thus be moved in or out without affecting the action of the break. A second winding F is shown outside the primary, from which it is quite disconnected and the ends of which are brought out to two independent terminals, S. This is the secondary coil and from which we obtain the secondary induced current. This secondary





Figs. 41 and 42.

coil is made to slide over the primary. It is thus brought more or less into the inductive influence of the latter, and the intensity of the electro-motive forces induced in the secondary coil controlled. The insertion or withdrawal of the iron core influences the secondary coil quite as much as the primary—but the presence or absence of the secondary coil has no influence on the primary.

In some coils with a fixed core, regulation is effected by means of a metal tube sliding over the iron core, thus screening the coils from the inductive action of the latter.

Various other methods of regulation have been employed such as (a) a variable resistance in the primary circuit to control the current from the battery, (b) a variable resistance in the circuit between the coil and the patient, (c) by means of a multiple contact switch by which more or less sections of the primary or secondary windings are brought into action. All of these methods are applicable and can be made to give the desired result more or less perfectly—but in all probability the sledge coil above shown—or one made after this plan—with separate contact breaker, removable iron core and sliding secondary coil, is the most generally useful of all. It gives the best regulation and being simple in construction is not likely to give much trouble by getting out of order.

The one part of such a coil most liable to cause trouble is the interrupter or contact-breaker. It is in fact the least satisfactory part of the instrument. The great fault is the difficulty of getting it to work evenly and smoothly for any length of time. Frequently the note emitted by the vibration of the spring will be heard to alter during an application and at the same time a change in the character of the current will be noticed.

As a rule those coils with a fixed iron core give less trouble in this way but they have such a narrow range of adjustment that their use is bound to be restricted in medical work. For portable batteries a revolving interrupting wheel to supply the primary coil with a simple interrupted current should not be difficult to arrange. If it possessed a considerable amount of momentum it would be free from sudden variations in speed. A clockwork motor would probably furnish sufficient power to drive the break as long as required for any ordinary application, and would not be too heavy to carry. For office use the small electric motor does the work in the best possible way.

Figure 43 shows a typical sledge coil with metal scale, and adjustable interrupter for slow or quick vibrations.

This is the most useful class of induction coil for medical work.

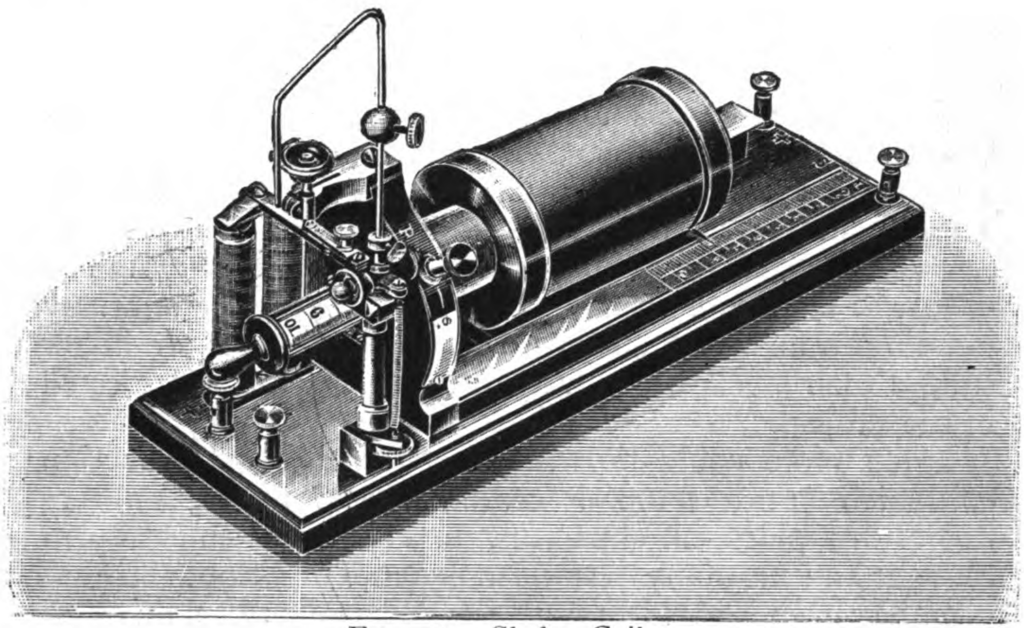


FIG. 43. Sledge Coil.

The one here shewn can be adjusted and give interruptions from one or two to about 100 per second. 50 per second is the average rate, and is very suitable for both diagnosis and treatment. Very slow interruptions produce powerful and painful contractions, while rapid interruptions cause little or no pain, and as the contractions run into each other, the total result is a condition of tetany in the muscles to which it is applied. In choosing a coil, if possible, let it be of the above sledge type, and always have it put in action before buying it. The interruptor deserves the closest scrutiny. See that it works smoothly when adjusted, for different rates of speed, and not too noisily. Whatever method of regulation is provided, it should be capable of gradual adjustment and not by jumps. The secondary coil should be tappped so that one-third, two-thirds, or the whole, may be used at will. This is equivalent to three secondary coils, and is a great advantage.

A short wire secondary gives a current of low electro motive force, but of large quantity. It suffers little by diffusion in the tissues, and consequently is capable of affecting deeply situated muscles.

A long wire secondary, on the other hand, gives a very small current, but a high electromotive force. As a result of diffusion, its effects are more or less limited to the skin and superficial muscles.

Unless there is any special reason to the contrary, the battery to work the coil should consist of one or perhaps two dry cells, especially if the apparatus is to be carried about. They stand any amount of rough usage, and fresh ones are easily obtainable by post, without any special precautions or fear of breakage. An inspection of the catalogue of any well-known maker of electro-medical instruments, or better still, of their stock, will be very instructive to those interested in the subject.

Much more could be written concerning the induction coil which, notwithstanding certain disadvantages, is a very interesting piece of apparatus, and one on which much thought and ingenuity has been expended. Enough, however, has been said to outline the main principles involved in their construction, and for further details, larger works should be consulted. A very complete chapter will be found in "Medical Electricity"—by Dr. H. Lewis Jones, 4th Edition.

Self-Induction Current—We have seen that by attaching electrodes to the end of the primary coil, we get the current of self-induction. A tracing of this current is not very easy to obtain, but if we examine a tracing of the exciting current in the primary coil, and notice the influence of the self-induction current on it, we will be able to form a fairly accurate idea of the latter. First take the case where the iron core is removed. It is something like this—

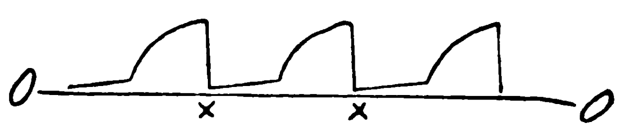


FIG. 44.

This represents three complete cycles. The first portion of each is the current coming in from the battery. Its e.m.f. is very low, and the tracing has a slight upward tendency, due to the impedance offered by the turns of the primary coil—the "back e.mf." as it is sometimes called. The effect is to delay the rise of the battery current by its full value. The end of this first portion corresponds to the moment the vibrator leaves the point of the contact screw, and the current is broken. But for the self-induction current, the line of the tracing would return to the zero line, and remain there until the current began to flow again. Instead of this, the curve suddenly rises, quickly reaching its maximum, which is much in excess of the e.m.f. of the original battery current. It falls away even more rapidly—due in some measure probably to the neutralising effect of the incoming current at the next "make." It will be seen that the current is never reversed in direction. So far as our sensations are concerned, the incoming battrey current is of too low e.m.f. to have any perceptible effect. The part which we are conscious of is the second which has its origin in the self-induction of the turns of the primary coil. It begins at the moment the vibrating spring leaves the contact screw and lasts practically until contact is made again. (In the case of an interrupter—set to give very slow "makes" and "breaks," it would be over before contact was made). The essential features of this current are that it is composed of short, unidirectional waves, between which there is a definite interval, and the strength or volume of current is not large. As ordinarily used, the sensory nerves are but slightly stimulated, and it thus becomes a very pleasant current for testing and treatment. The spark seen at the point of the contact screw is due to the self-induction current. We now insert the iron core, and see what happens. It may be noticed that the interrupter works more slowly—it will emit a lower pitched sound—and also that the spark at the point of the contact screw is increased in size.

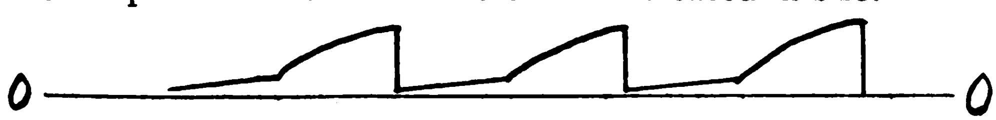


FIG. 45.

The effects of the iron is to give a slower, longer wave to both the incoming battery current, and to the self-induction current. The latter rises more slowly, and is still rising when the next contact is made. The e. m. f. and the current are both increased. It produces vigorous contractions, and stimulates the sensory nerves unpleasantly. In either case there is bound to be some interference by the chemical effects of electrolysis, because the current flowing through the patient's tissues, though constantly varying in strength, is always in the same direction.

Secondary Induced Current.—The secondary coil generally consists of a large number of turns of fine wire. It is not electrically connected in any way with the primary, but is wound on a bobbin, the hole through the centre of which is large enough to slide over the completed primary coil. By sliding it over the primary the secondary is brought more or less into the magnetic field of the primary, and the electromotive forces in it thereby adjusted. The secondary has from five to fifteen times the number of turns as the primary for which it is made. The average proportion of primary turns to secondary turns is 1 : 10. Most small portable coils have both primary and secondary wound on one bobbin. In the centre is fixed the iron core which is used to work the vibrator, and regulation is effected by a metal tube which is arranged to slide over the core, and thus screen its induction effects from the windings. This arrangement has the great advantage that the strength of the current can be varied without affecting the speed of the contact breaker. The effect of the large number of turns is to give sufficient amplitude to the e.m.f. at "make," so as to produce a perceptible current; also the impedance of the large number of turns of wire prevents the current at "break" rising to a proportionate degree—though it still exceeds the current at "make." The result is that we get from the secondary coil a current which is alternating in direction, but the waves in one direction are greater than the waves in the other direction. It consequently gives a tracing which is not symmetrical, like the simple alternating current, or the sinusoidal current, to be presently described. A tracing of the secondary induced current would be more or less like the following.

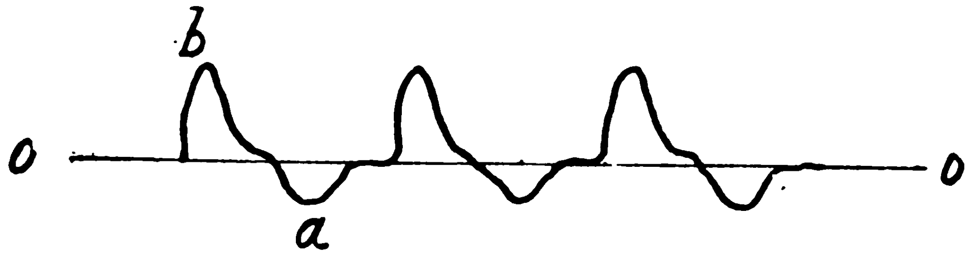


Fig. 46. (a) Current at make. (b) Current at break.

The effect of adding the iron core is to greatly prolong the current at "make," and to a lesser degree the current at "break." The tracing becomes less symmetrical, the current more painful in application, and less suitable for both testing and treatment.

As the current from an induction coil is so greatly influenced by so many factors in the circuit, all of which are more or less impossible to keep constant for any length of time it will cause no surprise to learn that it is impractible to reproduce any given set of circumstances at will. The more it is attempted the more difficult does it seem to become, until finally the struggle is abondoned, consoling one's self with the thought that most likely the time may be spent more profitably in other ways. From the fact that all the effects of our induction coil on living tissues can be imitated by means of the interruption or alternation of a constant current, which can be accurately measured, there seems little doubt that the latter will eventually supersede the induction coil in scientific investigation.

Before leaving the induction coil it is necessary to refer to the large Rhumkorff or spark coils, as they are called, such as are used for X-ray and other work. It is constructed on the same principle as the medical coil, but in a much larger scale, and special devices are employed to increase the discharge in the secondary coil at "break." A standard size will give a stream of sparks from ten to twelve inches long in air. On account of this enormous pressure the most elaborate precautions have to be taken in the way of insulation, especially between the primary and secondary windings. The primary coil is wound directly on the iron core from which it must be carefully insulated, and the whole is enclosed in a stout ebonite tube, not less than one-quarter of an inch thick. These tubes have to be most carefully selected, as the slightest flaw would be fatal to good results. The secondary is wound in sections on a special winding machine, and afterwards mounted on the tube. The secondary is so subdivided in order that no two wires between which there is any great difference of potential can come near each other. In a coil of the size above given the secondary would consist of not less than ten miles of wire, and probably more.

The interrupter for a spark coil is a matter of the first importance. For working with low pressures in the primary (12 to 20 volts), a platinum break is very suitable, but for pressures of 24 volts and upwards some form of mercury break is necessary, and there is no doubt that by the use of the latter the output of the coil can be very largely increased. The actual break is arranged to take place beneath the surface of some liquid having a high electrical resistance. Methylated spirit is probably the best. The main object is to produce a good contact at make and a sudden sharp break—the more sudden and complete this is the better the result.

These coils are usually mounted on a hollow base, inside which is placed another essential part of the apparatus—the condenser. This consists of a number of sheets of tin-foil, insulated from each other by one or more sheets of paraffined paper. Alternate sheets are connected together at one side, the intervening ones at the other, thus forming two distinct sets in close proximity, but insulated from each other. It is a modified form of Leyden jar, but takes up much less space than a jar of equal capacity. One set is connected to the pillar supporting the platinum contact screw, and the other to the spring carrying the iron block or armature—in a mercury break, to the parts corresponding to these—and its effect is to materially hasten the demagnetization of the iron core, which is essential.

At "make" the condenser is short-circuited, and consequently idle. At the moment of break the self-induction current, instead of bridging the contacts in the form of a spark, and making the interruption a gradual one, charges the condenser. This charge immediately discharges itself back into the primary, neutralising any self-induction current still remaining. Its practical value will be appreciated when it is stated that a coil capable of giving a ten-inch spark with a condenser in the primary circuit, will scarcely give an inch spark without it. Electrolytic breaks are very popular with some workers. The break is so sudden and complete, and the interruptions follow one another so rapidly that a condenser is of no assistance, and consequently unnecessary. In handling a large induction coil it is necessary to exercise great care, as the full current is quite capable of giving dangerous, or even fatal shocks.

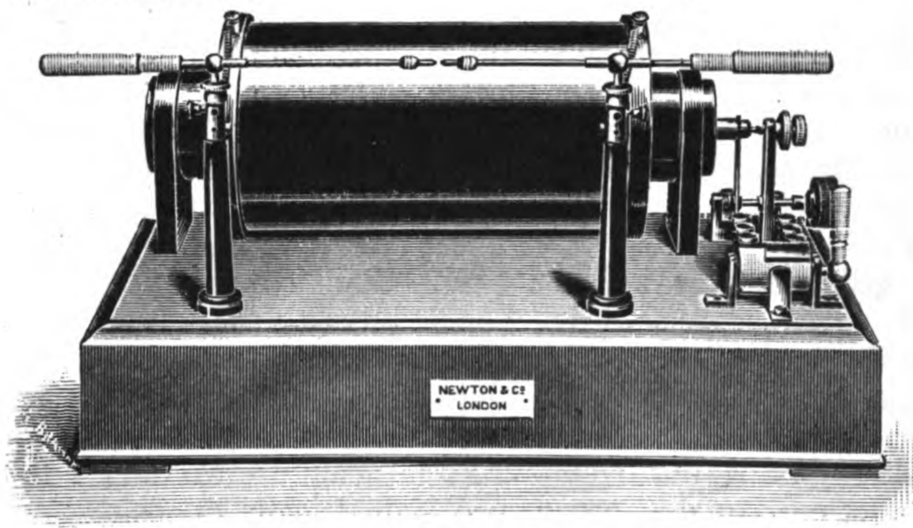


Fig. 47. Induction coil for X-ray and high frequency work.

These large coils are fully described in works dealing with X-rays and high frequency currents, where they find their greatest field of usefulness. They are also used to generate ultra violet rays by a special form of lamp. Only this brief description is permissible here, and that only on account of their use in the generation of high frequency currents, which now form a more or less important method of electrical treatment.

The spark coil is thus no more than a glorified edition of the medical coil. It is constructed on the same principle, and the character of the secondary discharge is essentially the same, and all the special devices employed to increase the efficiency of the apparatus have for their main object the suppression of the current at "make," and augmentation of the current at break."

It is impossible to deal even in the briefest way with the subject of X-rays,—mention is made here only on account of its intimate association with the induction coil. When the high tension discharge of a large coil is passed through an X-ray tube, the molecules of the residual air are set in extremely rapid motion. Those impinging on the cathode are given off again as cathode rays. The cathode being concave these rays are brought to a focus and at or near the focal point they are made to impinge on a solid body called the anti-cathode which is best made of platinum but more often aluminium. The immediate result is the production of X-rays, which are given off in straight lines from the point of impact. We use the electric current to generate X-rays, but X-rays are not electricity in the ordinary acceptance of the term—but rather a form of light with a wave length and rate of vibration different to ordinary light, and properties peculiar to itself.

Sinusoidal Current.—This is a very useful form of current, especially in connection with the electric bath. It has already been described in the first chapter where it was stated that its usual origin was from a dynamo electric machine. A dynamo may be made to give alternating current only, but by tapping the armature winding of any direct current dynamo, at two diametrically opposite points and connecting same to two slip rings, a sinusoidal current may be drawn off from the latter. It matters not whether the machine is driven as a dynamo, or fed with direct current and run as a motor, the sinusoidal current is obtained in the same manner. This enables one to obtain the current from a battery if a small motor is available to which slip rings have been added.

Where very slow alternations are required, special arrangements have to be made. It can be done with the motor but is very wasteful of current. One of the best methods is that of Ewing, of which the following is a description taken from Dr. Lewis Jones work on medical electricity.

"An insulating drum of ebonite is revolved in a glass cylindrical vessel of water which it nearly fills. There are metallic armatures CD inside the vessel at opposite ends of a diameter. Corresponding armatures A and B are fixed to

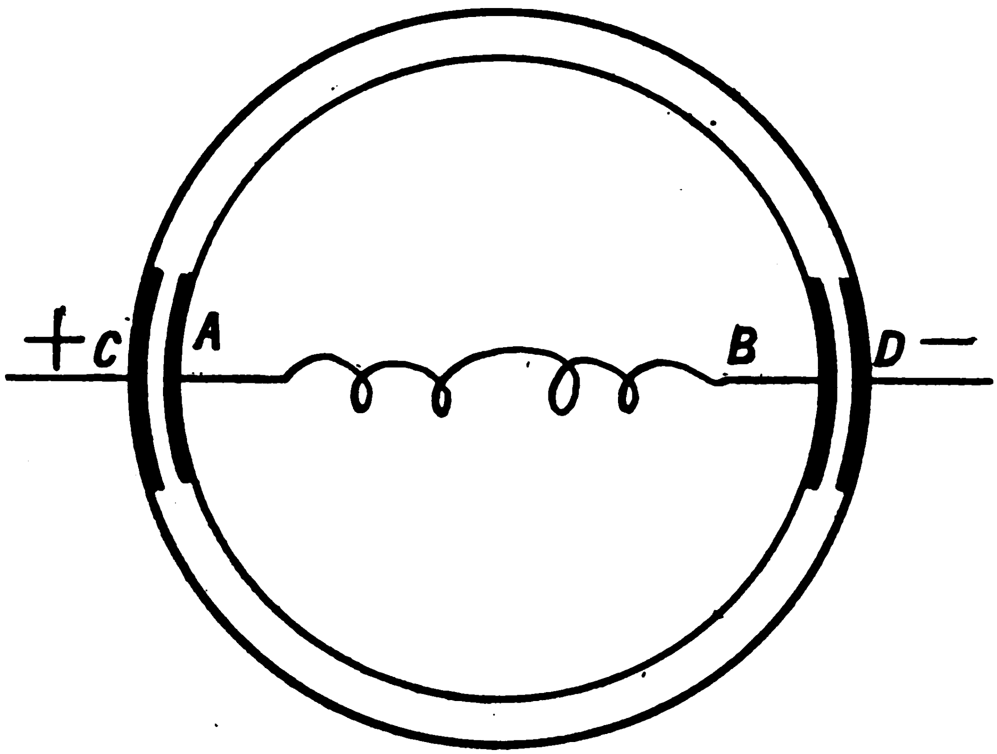


Fig. 48. Plan of Ewing's Rhythmic reverser.

the ebonite drum. If a difference of potential be maintained between C and D as indicated by the signs + and – there will be a flow of current from A to B through a conducting circuit joining these points, when the drum is in the position shown in the figure and if the drum is turned round through, 180° there will be a flow from B to A as the positions of A and B relative to the armatures C and D will have been reversed. Thus by rotating the ebonite drum a sinusoidal current will be set up in the circuit A B. It will reach its maximum when the armatures A and B are close to C and D and will be at zero when they occupy the positions at right angles to this. To utilise the current in the circuit A B it must be collected by means of rings and brushes very much in the way used with an alternating current dynamo."

A tracing of the sinusoidal current has already been given in the first chapter.

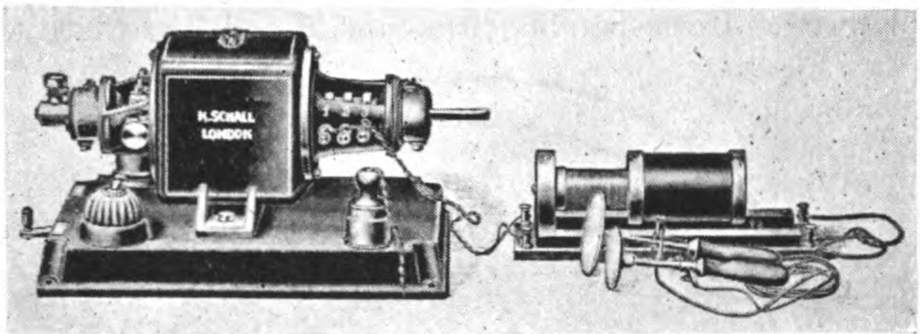


Fig. 49. Small motor for producing single phase sinusoidal currents, with rheostat for controlling the speed of the motor, and sledge coil to control the strength of the sinusoidal current.

Figure 49 shows a most useful appliance for obtaining sinusoidal current form a battery or other source of constant current. The current can be regulated in a most perfect manner by means of the sliding secondary coil.

High Frequency Currents.—It has been shown that the induction coil current is a modification of the constant current from which it is derived through the agency of electro-magnetic induction. Theoretically there is no reason why all the phenomena of the induction coil could not be reproduced with a large number of battery cells, but to produce the enormous e.m.f. of a large spark coil would require many thousands of cells, which is impracticable for many reasons. It should be remembered that the induction coil is no creator of energy—it is impossible to obtain from it or any other device for that matter—more energy than is put into it. As a transformer of electrical energy the efficiency of the induction coil is decidedly low. What we gain in increased pressure, we lose in quantity to an even greater degree. Fortunately the quantity of these high tension currents required in medical work is very small and easily supplied by any good make of coil, so that its comparatively low efficiency is not a matter of any consequence when we consider the great advantages it offers.

In experimenting with induction coil currents, they will be noticed by even a most casual observer, to have properties more or less in common with what is obtained from a static machine. The spark and brush discharges of both are very similar under certain conditions. They can both be used

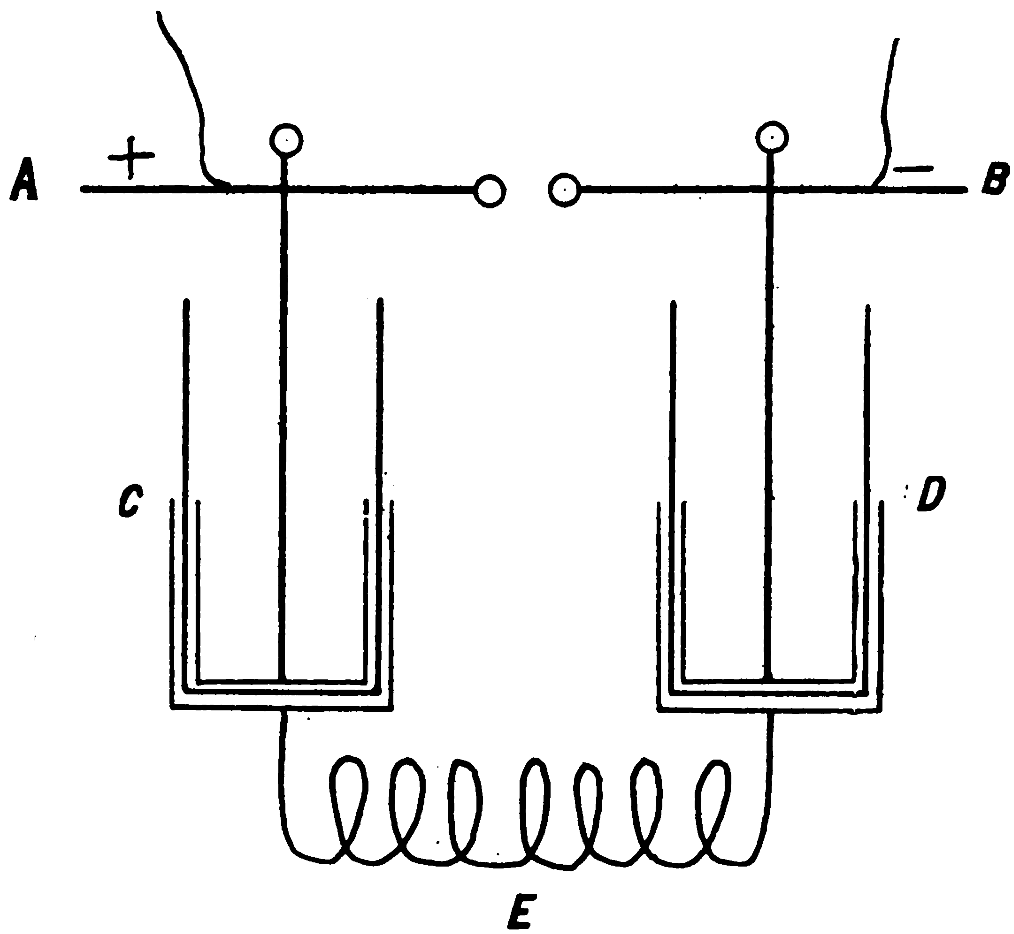


Fig. 50.

to charge Leyden jars with identical results, and the resemblance can be followed in other ways. For the production of high frequency currents the first step in the process is to charge a Leyden jar from some source of high tension current, and this may be a static machine, an induction coil, or a high potential alternating current transformer. The first gives the smallest output, while the greatest is obtained from the transformer. The induction coil is the source most generally used. Two jars are always used and their inner coatings connected to the terminals of the coil. The arrangement is best explained by means of a diagram. Fig. 50.

The wires carrying the high tension current are brought to the rods A B, which are connected to the inner coatings of the jars C D. The outer coatings are joined together by the spiral of coarse wire E. When the jars are charged to a sufficiently high potential they discharge across the knobs F. with the production of a bright and noisy spark. This spark, apparently single, is in reality made up of an enormous number of alternate discharges or oscillations which under certain conditions may reach many thousands, and even millions per second. With each oscillation, the charge of the inner coating is reversed, and this induces corresponding reversals in the outer coatings. These being joined by the spiral E. the latter becomes traversed by equally rapidly oscillating currents. Although the difference of potential between the outer coatings of the jars may be many thousands of volts, yet, so great is the amount of self-induction set up by currents alternating at this enormous frequency that this difference of potential is only partially reduced by joining them together with a copper wire, which may be one-quarter of an inch thick, and has been wound into a spiral of any number of turns from ten to twenty.

If we attach an electrode to each end of the spiral, exactly as was done in the case of the primary of the induction coil, and hold them in our hands, our body becomes traversed by the high frequency current, and if an ordinary incandescent lamp is placed in series on one side, so that the current must flow through the lamp before reaching the experimenter, the lamp will glow brightly, indicating the presence of a current of considerable magnitude, and yet no shock or unpleasant sensation will be felt so long as the electrodes are firmly grasped. If an amperemeter of the hot-wire form—fig. 51—which is independent of any magnetic effect, and records by means of the expansion of a wire which is more or less heated by the passage of the current, be inserted in place of the lamp, it will indicate a current of perhaps 0·6 of an ampere or more. To pass the same amount of constant current, or an alternating current of low frequency, through a person's body would be a most serious, if not fatal procedure. The reason for this apparent paradox has given rise to much discussion, but no complete explanation has yet been given. Another peculiar feature of these high frequeucy currents is what is called the

Fig. 51. High Frequency Milliamperemeter.

"skin effect"—that is, the current is not evenly distributed through the cross section of a solid conductor, but but confines itself to the surface; in other words, a thin walled metal tube conductor equally well as a solid conductor, of the same material and outer diameter. We are indebted to Elihu Thomson, Nikola Tesla, and D'Arsonval for most of what we know of high frequency and high potential currents, and the researches of the last named have given us the apparatus by which these currents are made available for medical work.

Figure 52 shews D'Arsonval's transformer, as it is called. The discharging knobs are enclosed in a box to confine the noise which is very objectionable to most persons. There is also a sliding contact by which more or less turns of the spiral are brought into action and the strength of the current in the patient's circuit thereby regulated. The spiral is always made of bare wire and freely exposed as shown in the figure.

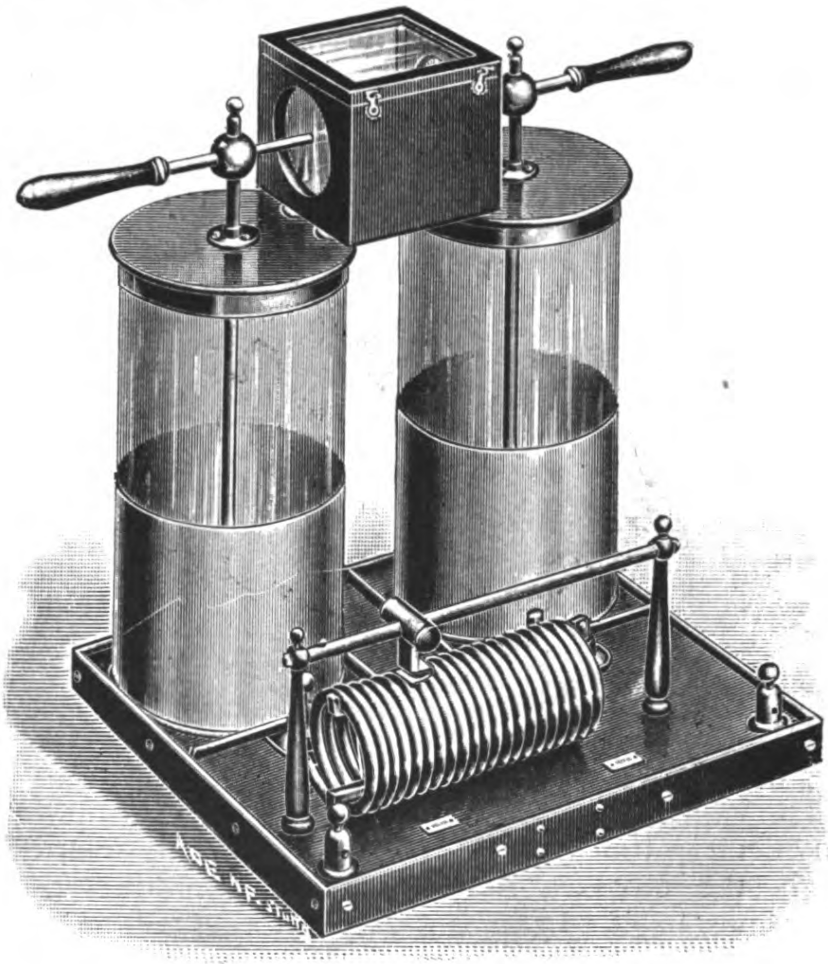


Fig. 52. D'Arsonval's Transformer.

This spiral is mostly used in the medical applications of high frequency currents. There are three principal methods employed. The first is by means of electrodes connected to the ends of the spiral as already explained. This is the direct method. The second form of application is somewhat different. The patient is connected, usually by a pair of metal handles, to *one* end of the spiral, while the other end is connected to a large metal plate which is near but not in contact with him. The usual arrangement is a cushion on which the patient reclines and underneath the cushion is placed the metal sheet. The cushion must not contain metal of any kind and should have a uniform thickness of about three inches. The patient and metal sheet form the coatings of a condenser system which are alternately charged and discharged by the oscillations of the currents from the ends of the spiral. This is the "condensation" method, or treatment by the condenser couch.

The third method is called treatment by auto-conduction. Here the wire spiral is made sufficiently large to completely enclose the patient. According to the form of the helix the patient stands, sits or reclines inside the cage thus formed. He does not touch any conductor, but is influenced inductively by the high frequency currents traversing the spiral or solenoid. Apparently the currents induced in his body are of some magnitude, since an incandescent lamp held between his two hands becomes illuminated.

All these three methods are essentially forms of general electrification differing only in degree from other methods of general electrification such as static electricity and the electric bath. The physiological effects noticed are those which give evidence of increased metabolism,—the amounts of CO_2 and urea being notably increased. There is also an increased dissapation of heat without any lowering of body temperature. So far as results are concerned the high frequency methods have not yet shown any conspicuous superiority.

It is in the use of high frequency currents for local applications that they have perhaps their greatest field of usefulness. For this purpose the apparatus has to be somewhat modified. There seems some reason to believe that the voltage between the two ends of the spiral is not so high as one might suppose from the effects produced, and to get the brush discharges necessary for local applications some method must be adapted to raise this voltage as high as possible. The principle involved is that of "resonance," and the resonator designed by Oudin in 1892 is the one in universal use.

It consists of a wooden cyclinder or cage about nine inches in diameter, and fifteen to eighteen inches high, and wound with about sixty turns of moderately coarse wire—the individual turns are about one quarter of an inch apart and should be evenly spaced at all points. The lower end of this wire is joined to some part of the thick wire spiral of the high frequency apparatus,—the best point being found by experiment. The upper end of the resonator terminates in a knob mounted on top of the instrument. It is possible to do without the coarse wire spiral and use instead the lower few turns of the resonator solenoid. The lower end is attached to the outer coating of one jar, while that of the other is attached to a point a little higher up changing it about until the best effect is produced. When the apparatus is set in action a profuse brush discharge is given off from the top of the resonator. This effect is increased when one end of the coarse wire spiral—or when this is not used, the lower end of the resonator winding,—is attached to earth, such as a gas or water pipe. To the upper knob electrodes are attached when it is required to make local applications.

Fig 53 shews a useful form of outfit which is arranged for both general and local treatment.

For local applications, many forms of electrodes are used. The simplest is what is called the brush electrode and consists of a metal plate from one to three inches in diameter and studded all over with a number of sharp metallic points or tufts of fine brass wires or tinsel

Other forms are made of closed glass tubes ,either filled with some couducting liquid as water or saline salution, or are exhausted until the partial vacuum produced becomes sufficiently conducting. They are sometimes called con denser electrodes because the internal conducting medium induces, when charged from the resonator, corresponding charges on the outside of the glass. When only a small portion of one's body is in contact with such an electrode in action, a sensation of heat is produced, and if it is moved a little away from the skin small sparks jump across the gap. The sparks increase in size and sensory effect the further it is removed from the skin until the distance is so great that they connot jump across. It will be noticed as the distance is increased the colour of the sparks changes from blue or violet—to white. These white sparks are to be avoided in most cases as they are very intense in their action and quite capable of producing burning and blistering

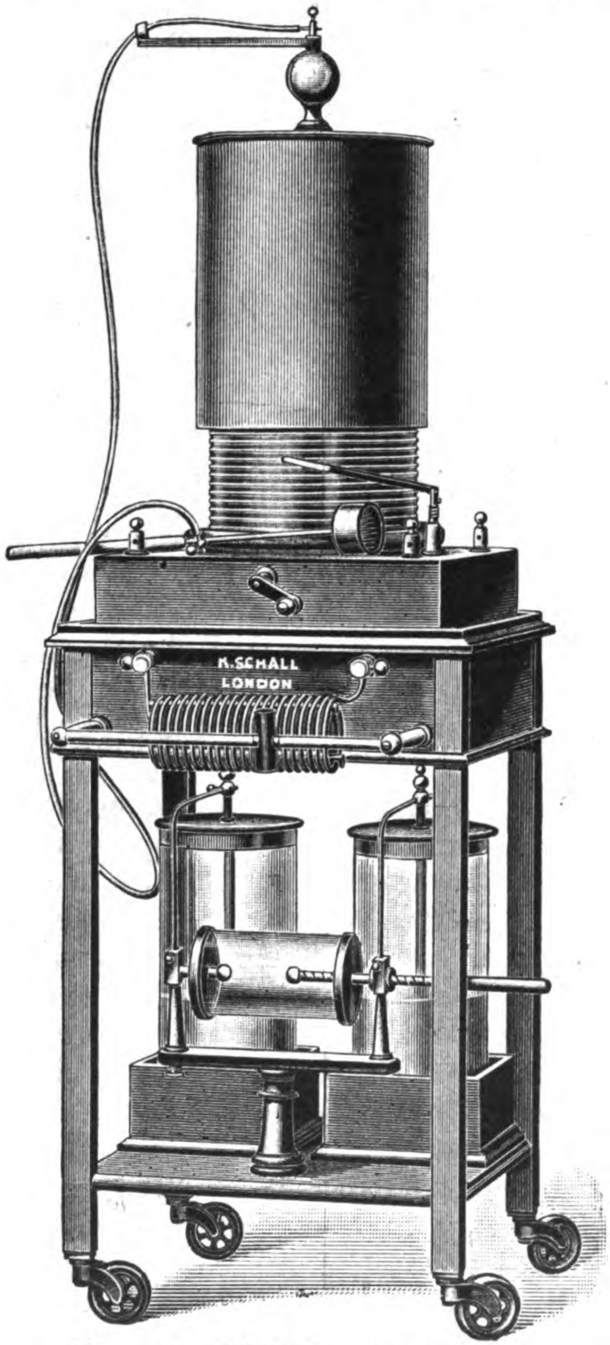


Fig. 53. High Frequency Outfit.

of the skin. The exhaustion of some of these vacuum electrodes is carried so far that X-rays are given off by them. They are useful when the ordinary X-ray tube is not permissable.

High frequency apparatus are made by many firms in this country and abroad and every maker has his own special design, so that there is ample room for choice in the selection of an outfit. Makers are generally very pleased to supply catalogues to probable purchasers in which they will find every conceivable form of instrument illustrated and described to an extent not possible here.

General applications of high frequency currents are indicated in rheumatism, rheumatoid arthritis, gout, diabetes, anaemia and general debility.

Local applications are employed with success in some diseases of the skin and mucous membranes—such as pruritus psoriasis, lupus, acne, eczema, obstinate ulcers, alopecia areata, etc. In local applications with the brush electrode the points are brought as near as possible without the white sparks jumping across, unless it is desired to produce a severe effect. The violet brush discharge is not at all painful. Condensor electrodes on the other hand are used in contact with the area to be treated and only moved away when it is desired to increase the effect.

Static Electricity.—The chief properties of static electricity were given in the first chapter and the main features of some static machines described. For therapeutic purposes the Wimshurst machine seems to be the most generally satisfactory in this country, and it should have at least eight plates of 30 inches diameter. It should be enclosed in a roomy case to prevent leakage as far as possible, and the case should be air tight. The essential features of the static current are that it is unidirectional if not absolutely constant, very high potential, and very small quantity. The amount of current is so slight that these very high potentials—which may be one hundred thousand volts or more—can be safely applied to patients. One reason for the small current is the enormously high internal resistance of the machine. This is due to some of their essential parts being constructed of the most highly insualting materials we know of.

Static machines are usually provided with a pair of Leyden jars, one of which is attached to each electrode or prime conductor if required. In most cases they should be removed. The accessory apparatus required are a platform with glass legs, a set of electrodes—single point, multiple point, ball, roller, and a handle for holding these,—also some light brass chain, such as used for bath plugs, for making connections to earth, etc. It is also useful to have a stand, the pillar of which is made of glass, for supporting electrodes. The machine will be most conveniently driven by a small motor of some kind.

It is important to know how to distinguish the poles of the machine. The most convenient method was first shewn the author by Dr. Lewis Jones and is described by him as follows :—" Take the earthed point electrode in the hand and present it to a knob of the machine in action. Gradually bringing it nearer and nearer, as it approaches the positive knob a star of light will appear on the point even at a distance of several inches, and this star of light will remain without much alteration until the point is brought up almost in contact with the knob, then small sparks pass. If approached to the negative pole in the same way, the discharge takes the form of a visible brush or spark when the point is still at a distance of two or three inches from the knob. It is easy to recognize these differences in the discharge to the point and from them to know which pole is positive and which is negative."

The simplest method of applying static electricity is that of simple charging—or the Static Bath as it is sometimes called. The patient is seated on the platform and connected to one pole of the machine—usually the positive. The negative pole is connected to earth, and the machine set in action. The patient is thus positively charged. Positive charging is more invigorating than negative, and in most cases to be preferrred. The general effects are sedative and tonic,—long applications of fifteen minutes or more are stimulating. It is indicated in that group of symptoms comprised in the words "nervous debility." Appetite and sleep are restored, and the symptoms of deranged nervous system, improved. Simple charging, positive or negative, forms an essential part of all static treatment, where the insulated platform is used. A modification of this method is to bring an earthed ball electrode near to the pole from which the patient is being charged. When brought sufficiently near, sparks pass and

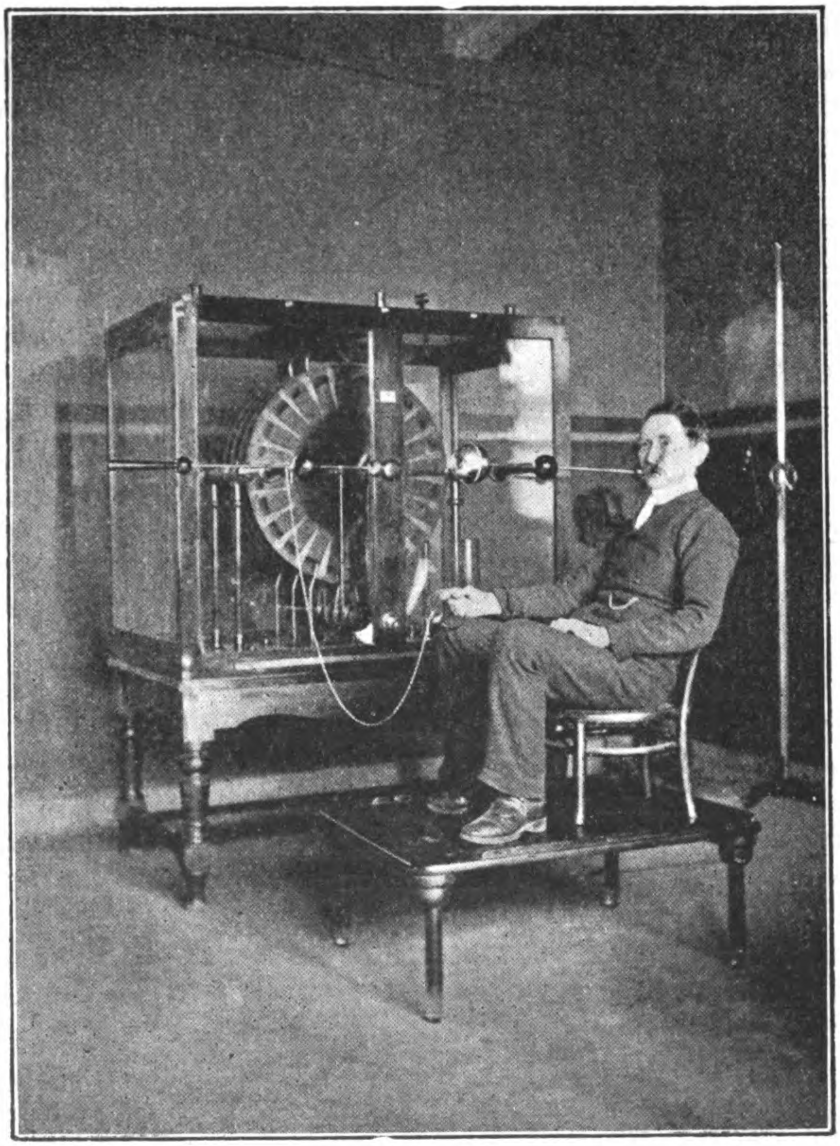


Fig. 54. Simple charging.

the patient is discharged, to be immediately charged again from the machine. The nearer the earthed knob is brought to the pole the more rapidly does this take place. This

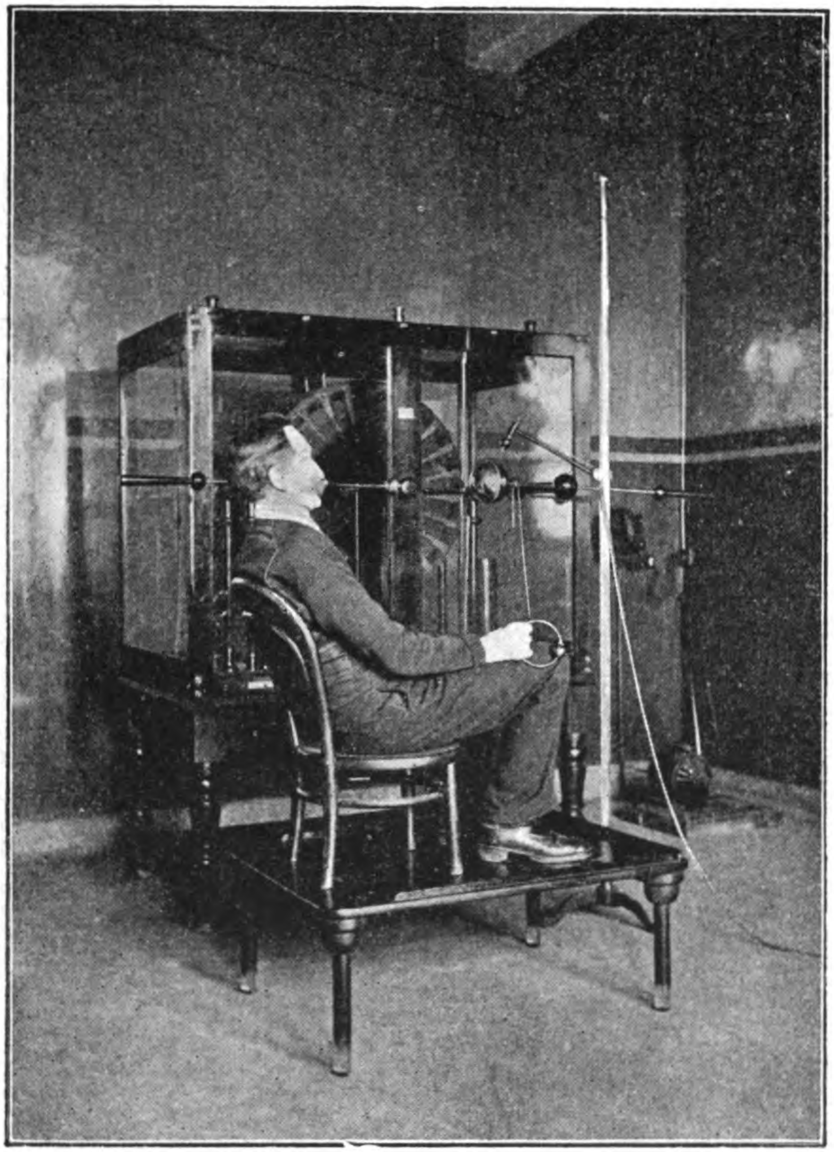


Fig. 55. Charge and discharge.

is treatment by *charge* and *discharge*, and was first discribed by Dr. Monell of Brooklyn. It is a more energetic method than simple charging—the effects and indications being the same. The noise of the sparks between the earthed knob and pole of the machine is sometimes a disadvantage.

The electric breeze.—The patient is arranged as for simple charging. An earthed point electrode—or multiple point—is brought near when a feeling as of a wind blowing towards him is experienced. The sensation is very pleasant when applied to the top of the head or back of the neck

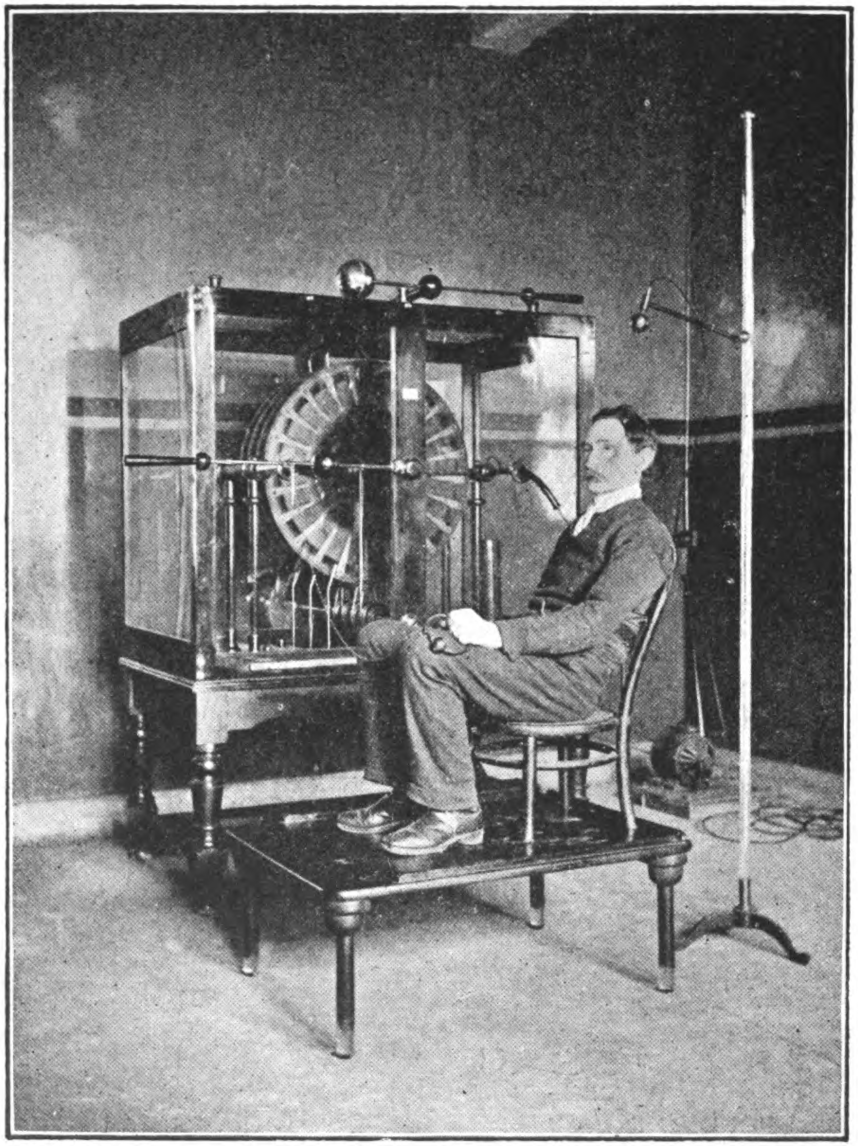


Fig. 56. Static breeze.

It is very like a hot douche with the advantage that the clothing need not be removed. The effect is invigorating. It is also useful for local application in certain cases of neuralgia and headache when the effect is at times completely satisfactory. The presence of metal about the patient's person may give rise to discomfort and have to be put aside during the application.

If the breeze is applied through the clothing the effect is of a hot prickling character. The best results are obtained when the patient's underclothing is quite free from the moisture of perspiration. The chief effect of the breeze is sedative, said to be even more so than the anode of the constant current.

Electrical sparks.—The patient is arranged again as for simple charging and an earthed knob brought close enough to allow one or more sparks to pass. It is better to allow but one at a time as the sensation is anything but pleasant. This is done by causing the electrode to describe a curve past the place at which it is desired the spark should strike. The proper distance is easily found, and if carried out skillfully and rapidly, the electrode is out of range before a second spark can pass. Sparks should not be directed on to bony prominences and must not be allowed to pass to the face, mammary glands or testicles. The effect can be decreased by the operator placing one foot on the platform and so allowing some of the charge to leak away.

The effect is very stimulating and has a very great moral effect in cases of hysteria and neurasthenia. It has given good results in chorea, constipation, and phantom tumor.

A modification of the above method consists in the use of a roller in place of the knob which is rolled over the clothed surface, a shower of stinging sparks passes to the patient. The thicker the layer of clothing the more intense the effect. In employing this method the operator should first place one foot on the platform and then bring the roller quickly to the place where it is required and sweep it quickly over the surfaces withdrawing the foot at the same time. In spark applications it is a good rule to always warn the patient of what is coming.

The Static Induced Current.—The elaboration of this method of using static electricity is due to Dr.

W. J. Morton of New York. The arrangement is to attach a Leyden jar by its inner coating to each pole of the static machine. An ordinary conducting cord and moist electrode is attached to each of the outer coatings of the jars. The knobs of the machine are set at about one eighth to one quarter of an inch apart. When the electrodes are applied to the patient, and the machine set in action, a shock is felt every time a spark passes between the knobs. The more the knobs are separated, or the larger the size of the jars, the greater the effect. The sensation is not unlike that of the secondary induced current from a medical induction coil, and by using small jars and the knobs close together, Dr. Morton claims it can set up strong contractions of muscles without any painful effect.

The general effects of static charging or its modifications, is to increase the frequency and regularity of the pulse, and to raise blood pressure. The action of the skin is increased and in common with other methods of general electrification, metabolic processes are stimulated, sleep and appetite return, where these functions have been impaired, and satisfactory results have been obtained in neurasthenia, insomnia, mental fatigue, melancholia, and also in the nervous disturbances which frequently accompany the menopause.

It has also proved useful in menstrual irregularities.

The Local effects are due to the stimulation of the sensory nerves, or to the strong muscular contraction, produced from the ball electrode, and perhaps the cathode rays which are given off by negatively electrified bodies. The sensory stimulation is useful in local pain as neuralgia, neuritis, and some forms of headache. Deep muscular pain and lumbago are frequently relieved by sparking. Recently cases of lupus, rodent ulcer and epithelioma have been treated by brush discharges—notably by Dr. Macintyre of Glasgow—and the results have been very encouraging. The method was to charge the patient negatively, and bring near the affected area a blunt point electrode connected to the positive pole. It is brought near enough for a profuse brush discharge to pass, but not actual sparks. It is not unlikely that these results will be found to be due to the cathode rays, which accompany the brush.

CHAPTER V

PHYSIOLOGY

In applying electrical currents to the human body for either diagnosis or treatment, it is important to remember we are dealing with what is essentially a membranous bag filled with saline solution and tissues of varying consistency. When we pass a current through it, or any part of it, all the phenomena of an electrolytic cell are present.

Chemical substances will accumulate at the poles, acids chiefly H Cl at the anode and alkalais, mostly Na HO, at the cathode. The body offers considerable resistance to the passage of the current, and further investigation shows that the total resistance is made up almost entirely by that of the skin itself. The resistance of the tissues beneath the skin is so low by comparison, that it may be neglected. Hard tissues such as bone and ligament have a higher resistance than softer tissues. The total resistance offered by any individual will depend in the first place upon the state of the skin as regards thickness, moisture and temperature—a thick, dry, and cold skin will offer the greatest, and a thin moist and warm skin the least resistance. Secondly the larger the electrode and the more perfectly it is applied to the skin the lower the resistance. It will be further noticed that the longer the current is applied, up to a certain point, the lower the resistance becomes—due to the gradually increasing vascularity and moisture of the skin under the electrode.

Under the ordinary conditions of medical work the resistance between the electrodes varies from 1000 to 3000 ohms.

Diffusion of current.—It has been shown that when a current of electricity is given a choice of more than one path it will divide itself up among them, the amount going by each path being in inverse proportion to its resistance. If we place the two electrodes upon the surface of the body, the latter being a conductor, innumerable paths are offered to it, most of the current will pass by the most direct or path of least resistance—and here the *density of current* will be greatest. If we imagine the current of electricity to be made up of thin lines or strands, where the density is greatest they are gathered together as in a cord. If the cord is frayed out the density is less but the same number of lines are there. In its passage from one electrode to the other no lines are lost but some of them will take a very circuituous route before being finally gathered in at the cathode. If one electrode is larger than the other the density will be greater at the smaller. A certain minimum density of current is necessary to produce appreciable physiological or therapentical results and one may safely say that with the currents used in medical electricity the density in the outlying regions away from the direct line between the electrodes are so slight as to be of no importance. If the two electrodes are placed close together, as in fig. 57, practically the whole current travels

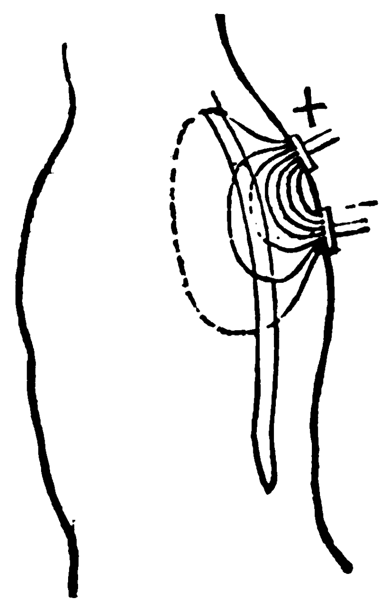
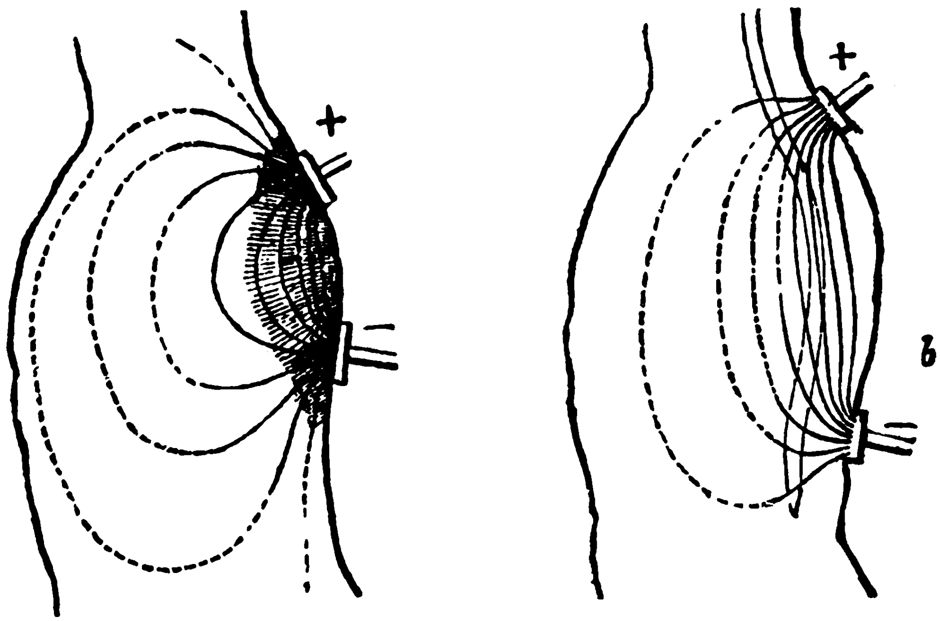


Fig. 57

through the tissues immediately beneath the skin, as we move them further apart there is greater diffusion and the area of greatest density becomes less superficial. Figs. 58 and 59.

The practical value of the above is obvious when we come to apply electricity in treatment.



Figs. 58 and 59.

To influence deep seated structures large electrodes are to be used and they must be placed some distance apart. If a small superficial area is to be treated—such as a case of neuralgia of a superficial nerve—a small electrode—usually the anode—is placed over the painful spot, and a large electrode is placed on the sternum or some distant part. In this way the current density—at the small or active electrode can be adjusted to produce definite effects while no appreciable effects take place at the large or indifferent electrode because the same amount of current is spread over an area which may be from twenty to fifty times greater, and the current density proportinately reduced.

The action of electricity on the tissues.—The physiological action of electricity is a matter of the first importance to the electro-therapeutist, and is one that is still wrapped in more or less obscurity, resembling in this respect that class of medicinal substances known as alternatives. The power possessed by both to do good when intelligently used, is undoubted, but the manner in which these good results are brought about is a matter of less certainty. So far as electricity is concerned it would seem that the further study of electrolysis or electrolytic conduction has afforded some information on the subject. As has been already stated in applying electric currents to the human body we are dealing with an electrolytic conductor in which all the essential phenomena of electrolysis take place. These have already been given briefly in the first chapter.

For the sake of simplicity we will consider that the membranous bag—the skin—is filled with a 0·5 per cent. solution of sodium chloride which represents the juices of the body very fairly. If the electrodes are applied, and the current passed, the chlorine ions accumulate at the *anode*, either to be set free as such or to enter into fresh combinations forming, H Cl and oxygen, or combining with the metal of the anode to form chlorides, etc. The sodium ions are repelled and travel towards the cathode. At the cathode the converse takes place—the sodium ions being attracted, which by secondary reaction appear as caustic soda and hydrogen gas, and the chlorine ions are repelled and travel towards the anode.

It is easily seen that if these electrolytic products were allowed to accumulate in the skin as would be the case if bare metal electrodes were used, severe burning or blistering would result at the points of contact after passing large currents for any length of time. It is for this reason electrodes are always covered with some absorbent material, which being well wetted, absorbs and dilutes these irritating substances. While the above does very well to illustrate the principles underlying electrolytic conduction in the tissues, what actually does take place is not so simple. The current in its passage encounters fluids and tissues of various compositions and consistencies. In the very general migration of ions that takes place, it is conceivable there may be a stimulant to cell energy and cell regeneration. Luduc of Nantes has made most important experiments, demonstrating the migration of ions through the tissues, and he is of the opinion that many of the observed effects of electricity on tissues are due to this redistribution of the ions. There is also another matter for consideration. The body tissues being of varied composition and consistency, will have certain electrical relations to each other, irrespective of that brought about by their relative position to the direction of flow of current—so that one tissue may be electro-positive to another tissue adjoining it—all are in a sense immersed in an electrolyte, and during the passage of a current the various tissues will become more or less polarised to each other in the same way that there is polarisation of the plates of an accumulator resulting in the storage of electrical energy. It has been shewn that there is a strong back current from tissues which have been subjected to the inflnence of a constant current for some time. How far this may be due to the electrolytic products acting on the metal electrodes is not certain but there seems no doubt that some rearrangement of molecules does take place in the tissues and the compounds thus formed, as well as the electrolytic process itself, may be largely responsible for the effects of electrical treatment.

Cataphoresis.—This term is applied to the movement of electrolytic solutions in the direction of flow of current, which movement can take place through membrane or any porous diaphragm against the force of gravity. For this reason it has also been called electric osmosis. From what has just been said there will of course be present all the phenomena of electrolysis with the migration of ions, formation of new compounds and so on. This, in fact, would seem to be the only point of any importance so far as the practical application of this property in treatment is concerned—that is the introduction of chemical substances into the body through the skin.

As a method of administering drugs it has many disadvantages. To begin with, it is too elaborate, it is impossible to be sure how much is given, and the drug once through the skin is rapidly washed away by the circulation. There are, however, certain circumstances under which it has a definite value. By soaking the cover of the anode with a 10°/₀ solution of cocaine in guiacol, and applying it to the skin, the latter can be made anæsthetic in a few minutes with a current of about five milleamperes. This may be more convenient sometimes than using the hypodermic needle.

Good results have followed the application of lithium salts in this way for the removal of gouty deposits, and some American writers speak very highly of the method for the removal of inflammatory exudates by the local introduction of a watery solution of iodine. The local application of magnesium sulphate by this method for the removal of multiple warts was completely successful in a case reported recently by Reus of Chemoga. The patient was a native of India and the warts were situated over the greater part of the scalp. A saturated solution of potassium magnesium sulphate was employed. Several thicknesses of lint were soaked in this and placed over the head. An electrode of potters' clay was applied on top and connected to the negative pole. The indifferent electrode was a bath of water connected to the positive pole in which the patients feet and legs were immersed. The current employed varied from 7 milliamperes at the beginning to 35 milliamperes at the end —the application lasting twenty-five minutes. Ten days afterwards the warts had entirely disappeared. It will be noticed that to introduce cocaine we used the anode as the active electrode—in the case just mentioned it was the cathode. Substances vary in this respect and care must be taken to employ the proper pole when using any given drug. Another point of importance is the selection of a proper solvent for the drug to be introduced. Water does for many but not for all. In the case of cocain, guiacol has been found most suitable.

Those who wish to take up this subject seriously should obtain the treatise on cataphoresis by Dr. W. J. Morton of New York.

In all that has been said about electrolytic conduction in the tissues and cataphoresis the use of the constant current is implied—being the one which possesses the greatest electro-chemical action. There is practically no electrolytic action caused by alternating, faradic, or static currents. In the case of the first two the successive impulses tend to neutralise each other, and the strength of current from a static machine is so small that chemical effects, if any, are inappreciable.

The presence of electrical currents has been demonstrated in most living tissues, and many interesting measurements of speed, etc. have been made. It is important to remember, however, that nerve impulses are not electrical.

We can more or less simulate the results of a nervous *impulse* by a current of electricity, but the resemblance ends there. If nerve impulses were electrical then if the two ends of a divided nerve were brought into contact with a piece of silver or other metal, the continuity of the nerve for nervous impulses would be restored. This does not take place, and so far as we know normal uninjured nerve tissue is the only conductor for nervous impulses.

Electrotonus.—When a constant current is made to traverse a nerve certain changes take place as regards its conductivity and irritability, especially in the immediate region of the electrodes. The changes which take place at the anode—anelectrotonus—are not the same as those about the kathode—kathelectrotonus.

At the anode the irritability of the nerve is diminished, as also is its conductivity for nervous impulses, due to the development of an area round the anode which resists the passage of nervous impulses.

At the kathode there is an increase in irritability which rises suddenly at closure and is maintained during the flow of the current. The suddeness of the rise acts as a stimulus to the nerve.

In either case there is a gradual return to normal conditions after the current has ceased to flow.

These facts are of the first importance in guiding us in treatment, and also in partly explaining the behaviour of muscle towards constant currents at their "make" or closure, and "break" or opening of the circuit.

Reactions of nerve and muscle.—If an electrode carrying a galvanic current be placed over a motor nerve—the other electrode being placed on some other part of the body—contractions in the muscles supplied by the nerve will occur provided the current is strong enough and alternately made and broken. For these purposes the active electrode is provided with a key which when depressed allows the current to flow. Others are made which allow the current to flow except when the key is depressed, but they are not so convenient.

The student who has, or can gain access to, a galvanic or constant current battery should practise these normal reactions on himself—the ulnar nerve at the bend of the elbow being most convenient for this purpose. As the current is gradually increased contractions will appear first when the circuit is closed, then as the current strength increases both at closure and opening. If the direction of flow is reversed from time to time, it will be observed that contractions are more easy to obtain when the active electrode is negative.

If the minimum strength of current, as shown by the galvanometer, necessary to obtain a definite contraction he noted, it will be found that they appear in this order:—

1. Kathodal closing contraction (KCC) 2 M.A.
2. Anodal ,, ,, (ACC) 3 ,, ,,
3. Anodal opening ,, (AOC) 3.5 ,, ,,
4. Kathodal ,, ,, (KOC) 15 ,, ,,

The current strength given is rather high but the figures show the relative amount required to produce the contractions. These figures will vary according to the nerve examined—whether superficial or deep—and the stoutness or otherwise of the individual. The more deeply a nerve is imbedded the more current is lost to it by diffusion, and this has to be made up by increasing the total current passing at the electrode. With a small negative electrode placed as close as possible to the ulnar nerve at the elbow contractions generally begin to appear with a current of one milliampere. The contraction takes place at closure, as a sudden quick jerk, and the muscle relaxes completely or nearly so, even though the current continues to flow.

If strong currents are used it will be noticed that the muscle does not completely relax, after the first contraction at closure, so long as the current is not cut off.

This is called duration tetanus.

Kathodal duration tetauus (KDT) is more easy to obtain than anodal duration tetanus (ADT). It is not seen in normal muscles except when strong currents, greatly in excess of those usually required in testing, are employed.

Muscle will react to direct stimulation of its fibres, but in health this is not easy of demonstration. The intramuscular nerve fibres receive and conduct electricity more readily than the muscle itself, so that their stimulation causes a contraction which obscures effectually anything which might occur if the nerve fibres were not present.

If instead of a constant current we use a simple interrupted, simple alternating, or induction coil current, the contractions will tend to run together so as to produce a state of tetanus, provided the electrical impulses follow one another at a rate of about twenty per second or higher.

From the above it will be seen that under normal conditions a muscle contracts to electrical impulses when the stimulus is applied either to its motor nerve trunk, or to the muscle itself—the effect in both cases being due to stimulation of the motor nerves of the muscle.

It is worthy of note that in a curarised animal, electrical stimulation of a motor nerve causes no contraction of the muscles supplied by it, but if the stimulus be applied to the muscles directly they react in a practically normal manner to both constant and interrupted currents.

Sensory Nerves.—The application of a constant current to the skin is, under certain conditions, attended by sensations which are more or less characteristic. These are of peculiar pin-pricking kind, which later becomes a steady burning pain. If the electrodes are of equal size, this effect is more perceptible at the kathode, but if one be much smaller than the other, more sensory effect occurs at the smaller, on account of the greater density of current there, whether it be anode or kathode. The primary pin-pricking sensation is probably due to the current itself acting on the nerve endings as it passes through—the subsequent burning pain is the result of the irritant action of the chemical products of electrolysis.

The sensations produced by alternating or induction coil currents depends on the frequency. If very slow each "make" and "break" is like that of a constant current similarily made and broken—that is, a series of slight shocks, and these shocks are recognisable individually up to forty or fifty impulses per second. After this the sensations tend to run together, and the total effect becomes much less unpleasant. At frequencies of one hundred per second or more, a sense of numbness and anæsthesia is perceived which may spread over the whole area supplied by the sensory nerve if the electrode is placed over its trunk. Dry bare metal electrodes may be used here since the local electro-chemical effects are too slight to be of any importance, but the sensations are much more severe and painful.

With a simple interrupted current the sensations are composed of a combination of the above. The successive "makes" and "breaks" cause sensations similar to those of an induction coil current of the same frequency, and as the impulses are all in the same direction, electrolytic products accumulate at the areas under the electrodes, causing the burning pain which attends the application of the constant current, provided the current density is sufficiently high. With low densities the electrolytic products are carried away by the circulation as quickly as formed.

Nerves of Special Sense.—Since electrical stimulation of ordinary sensory nerves gives rise to those sensations which they are designed to convey, so do the nerves of special sense respond by their own special sensations. This can be shown by a very simple experiment. Take a clean silver coin and a piece of zinc of the same size. Place one on the upper surface of the tongue, and the other underneath. Compress them lightly between the finger and thumb and draw them forward until they come together by their front edges. At the moment of contact there will be a sensation as of a flash of light, and also of a sharp metallic taste in the mouth. The optic nerve is very sensitive to electrical currents. In this case the small diffusion current is enough to produce appreciable stimulation. The metallic taste is due to the stimulation of the nerves of taste. This taste is often experienced by patients taking a course of galvanic baths, where the water comes up over the shoulders. For proper stimulation of the optic nerves the indifferent electrode should be placed on the back of the neck, and the active electrode on the eyelids. In experimenting this way only only the weakest possible currents are to be used, as strong currents may cause irreparable damage to the retina.

Stimulation of the auditory nerves causes the sensations of sound, but fairly large currents are required, and the accompanying effects on the eyes, brain, and facial muscles, are unpleasant. Stimulation of the olfactory nerve is said to give the impression of a smell like sulphur or phosphorus.

All these effects are most easily produced by the "make" and "break" of the constant current,--the effect of the faradic or coil current being much less marked. The same thing is observed in applying current to the brain through the skull--the coil current having very little effect. Constant current applied transversely produces giddiness with a tendency to fall towards the anode. As regards its action on special organs, the point to remember is that the effect of electricity is mainly a stimulating one, so far as living tissues are concerned, and consequently electrical stimulation should be accompanied or followed by increased activity of the organ experimented upon. In organs made up mainly of unstriped muscle contractions are set up. The gall bladder can be made to contract in this way, likewise the urinary bladder and uterus. Stimulation of the muscular coat of the intestine increases peristalsis. The activity of secreting glands is also increased by electrical currents.

Effects on General Nutrition.—Rockwell conducted some experiments on this point, and found that young dogs who were treated by general faradisation gained weight more quickly and were perceptibly larger than others of same litter not so treated, but brought up under exactly similar conditions. Others have found that if the muscles of, say one leg be treated regularly for three or four weeks by electrical methods they became larger and heavier than those of the opposite leg.

It was also found that for general nutritional effects constantly varying currents are best, such as the rythmical interrupted, sinusoidal or induction coil. Static electricity and the constant current are not so useful in this respect.

Magnetism, *per se*, seems to have no action at all on the tissues or vital processes. Elaborate experiments have been carried out with magnets of enormous power. They were entirely without result, immediate or remote. It is scarcely necessary to mention that magnetic finger rings, and other articles of a similar nature, worn or carried by some people for curative or prophylactic reasons, have a purely suggestive effect, and would be equally useful if made of non-magnetic material, so long as the individual were not informed of the fact.

CHAPTER VI

DIAGNOSIS

In the previous chapter the reaction of normal tissues and structures to electrical stimuli has been briefly outlined. In certain conditions of disease it is found that these reactions become modified more or less, and it is upon this fact that electro-diagnosis is based. Its greatest value lies in the help it gives in clearing up otherwise obscure points in the diagnosis of many diseases affecting the nervous and muscular systems. The reactions of nerves and muscles to this form of stimulus take place quite independently of the will of the individual under examination, they are visible, and afford definite information. For practical testing we require a source of simple alternating or induction coil current, and a source of continuous current. The combined battery is the most convenient apparatus at present available. It should be provided with a milliamperemeter, and a switch for reversing the current. For electrodes, one about 2 × 4 inches, the indifferent electrode, is placed on the sternum preferably, owing to the absence of nerves and muscles and because the patient can assist the operator by holding it in position with one hand. It may be placed down the back of the neck where it will be retained by the pressure of the clothing, or if the patient is reclining it may be placed under the hips. It is essential for this electrode to be of comparatively large size, that part of its cover which comes between the metal and the patient must be thoroughly moistened, and it is to be accurately adapted to the contour of the surface and maintained there by firm pressure. The active electrode is a covered disc about three-quarters of an inch in diameter and mounted on a handle with a "closing" key, fig. 29. Both electrodes are to be well soaked in warm water. Under ordinary circumstances it is not necessary to add common salt or carbonate of soda to the water. Though such addition does greatly reduce the resistance of the skin, it has a destructive action on the electrodes. When it is desired to test the intrinsic muscles of the hands and feet it will be found best to place the indifferent electrode on the opposite side of the hand or foot being tested. The current thus passes straight through the muscles and their contraction is more easily obtained.

The part to be tested should be in a state of rest, the muscles completely relaxed, and the more the skin is moistened the more easily will the reactions be produced.

The operator should first take hold of the limb to be tested and pass the current through his hand to the part. This not only gives the operator an idea of the strength of the current, but has a reassuring effect on the patient. Strong or painful currents are never necessary in electrical testing. All that is required is enough to produce a perceptible contraction. In testing, always begin with the coil current, reserving the constant or battery current for the last. As far as possible always use the same apparatus. Whatever method is employed for regulating the strength of the coil current the necessary adjustment of the core or secondary coil to give definite contractions under normal conditions should be noted. This will only be arrived at after some practice, but in the meantime much valuable information will be gained. The method is a rough one, but in the absence of a reliable instrument for measuring induction coil currents it answers fairly well. It is for this reason that the simple alternating current is likely to displace the coil current in testing. The amount of current used can be accurately measured and exactly the same conditions can be reproduced as often as desired. Moreover it can be so adjusted that while causing strong contractions the sensory nerves are scarcely if at all affected—that is to say, no sense of pain is experienced by the patient as is the case with the current from many induction coils.

In using the constant current the milleamperemeter is our infallible guide. If a contraction is not obtained the reading may show that too little current is flowing—due perhaps to dryness of the skin, or too low electro-motive force. Make the conditions as to size of electrodes moisture of skin, etc. as nearly alike as possible in all cases and note the amount of current required to obtain a definite amount of contraction. The careful cultivation of this habit saves much time and uncertainty in arriving at a conclusion.

It should be remembered that it is only the superficial nerves and muscles which can be tested with any accurate results, but fortunately they afford the required information in practically all cases. To enable a sufficient current density to reach a deep muscle the total current would be so large as to cause violent contractions in all the surrounding muscles which would mask everything else.

It is assumed that the operator has a knowledge of the anatomy of the muscular and nervous systems, including the action and nerve supply of the individual muscles and cutaneous areas. Such knowledge is absolutely essential if the examination is to have any value.

It is found that when stimulating any normal muscle in the ordinary way employed in testing, that there is a point where the contraction is greater, or in other words, when the minimal contraction is obtained with a smaller current, than when the electrode is even but slightly moved from this point. This is called the motor point of the muscle. Each muscle has its motor point, and it is found to correspond to the spot where its motor nerve enters the substance of the muscle. A thorough knowledge of motor points enables one to carry out a test with the smallest possible amount of current and consequently less discomfort to the patient. Speaking generally the motor point is situated about the middle of the body of a muscle. Thus the beginner by calling up a mental picture of the muscle it is desired to stimulate and placing the active electrode over the middle of its thickest part will be either on the point or so near that very little exploring will discover it. This does not apply to all the muscles but it does apply to a great many and a knowledge of this fact is a great help and encouragement to the beginner. It is important to point out that is not necessary, even if it were always possible, to throw the whole muscle into strong visible contraction. Some muscles do come up strongly and visibly with moderate currents, of which the biceps in the arm is a good example. The action of others is found by placing the finger lightly over the tendon at the moment of closing the current. In this way the slightest contraction becomes manifest. The muscles, whose tendons are gathered about the wrist and ankle are examples. Others again are only manifest when the characteristic action of the muscle takes place, such as the supinator brevis.

Muscles which are too feeble to produce their characteristic action can only be detected by some slight movement on the surface near the electrode. The plates given show the position of the motor points—they should be referred to continually until the operator is perfectly familiar with them.

The points for stimulating the principal nerve trunks are also shewn.

When it is desired to form a general opinion as to the conducting power of an individual's motor nerves, Erb. has suggested the testing of four pairs of nerves—the frontal branch of the facial, spinal accessory in the neck, the uluar and the peroneal.

These have been selected after much investigation, and he finds that the results are practically the same on both sides of the body and the four pairs of nerves are equally irritable to the same minimum of current. These nerves are easy to get at and in many cases it is best to begin a test by stimulating them. It always affords information of a definite character which may throw valuable light on the nature of the disorder.

In addition to these, an accurate knowledge of the position of other important nerve trunks is essential, particularly in cases of injury or division of the trunks or their branches.

The following table, taken from Lewis Jones' "Medical Electricity," gives the position of the most important nerves and the points favourable for their stimulation.

In the upper limb:

1. *The median*—Along the inner border of the biceps and at the bend of the elbow.
2. *The Uluar*—In the groove between the internal condyle and the olecranon.
3. *The musculo-spiral*—At the point where it emerges from the triceps, namely, on the outer side of the upper arm about the junction of the middle and lower thirds.
4. *The musculo-cutaneous*—Between the biceps and coraco-brachialis muscles.
5. *The long thoracic* (serratus magnus)—On the inner wall of the axilla.
6. *The supra clavicular point* of Erb—"At a spot one inch above the clavicle and a little externally to the posterior border of the sterno-mastoid, immediately in front of the transverse process of the sixth cervical vertebrae, a simultaneous contradiction can be produced in the deltoid, biceps, coraco-brachialis, brachialis anticus, and supinator longus."

This is a motor point for the fifth and sixth cervical roots before they reach the brachial plexus.

In the lower limb:

7. *The anterior crural*—In the fold of the groin just outside the femoral artery.
8. *The sciatic*—Just below the gluteal fold at the back of the thigh.
9. *The internal popliteal*—In the popliteal space and to the inner side of the tendo Achillis.
10. *The peroneal nerve*—Just above the head of the fibula beside the biceps tendon.

In the face:

11. *The facial*—Through the cartilage of the lower surface of the meatus auditorius. Its chief ramifications can be reached where they emerge from the parotid gland.
12. *The fifth*—At the supraorbital foramen, at the infraorbital foramen, at the foramen mentale, on the side of the tongue.

In the neck:

13. *The spinal accessory*—At the top of the supra clavicular triangle, where the nerve pierces the sterno-mastoid.

14. *The phrenic*—On the outer edge of the lower part of the sterno-mastoid.
15. *The hypoglossal*—Along the upper border of the great cornu of the hyoid bone.
16. *The recurrent laryngeal*— Along the outer border of the trachea.
17. *The pneumo-gastric* and *glosso-pharyngeal*—Along the track of the carotid artery, just below the angle of the jaw.

It frequently happens that paralysis affects a group of muscles which does not correspond to the distribution of any particular nerve trunk.

In such a case it is a great help to be able to trace back the nerve supply to the spinal roots--a matter of considerable difficulty if a plexus intervenes between the nerve trunks and the spinal cord. The following table, from the same source, shewing the muscles represented in certain cervical and lumbar segments is very likely to be of much help in locating the lesion in cases of this kind.

Segments :

4th cervical—Diaphragm, levator anguli ⁝ scapulae, deltoid, rhomboids, spinati, biceps, supinator longus.

5th cervical—Rhomboids, spinati, teres minor, deltoid, pectoralis major (clavicular portion) biceps, serratus magnus, supinator longus and brevis.

6th cervical—Latissimus dorsi, pectoralis major, serratus magnus, pronators, biceps, triceps, brachialis anticus, extensors of wrist and fingers.

7th cervical—Teres major, latissimus dorsi, subscapularis, pectoralis major and minor, triceps, flexors of wrist and fingers.

8th cervical—Flexors of wrist and fingers, extensors of thumb, intrinsic muscles of hand.

1st dorsal—Extensors of thumb, intrinsic muscles of hand, (thenar, hypothenar, interossii).

3rd lumbar—Ilio-psoas, sartorius, adductors extensor cruris.

4th lumbar—Extensor femoris et cruris, peroneus longus adductors.

5th lumbar—Flexors and extensors of toes, tibial, sural, and peroneal muscles, extensors and rotators of thigh, hamstrings.

1st sacral—Calf, hamstrings, long flexor of great toe, intrinsic muscles of foot.

2nd sacral—Intrinsic muscles of foot.

The chief points in carrying out a test may be briefly stated here :—

Always commence with the coil and use the same size of active electrode in all cases. The indifferent electrode may be any size so long as it has not less than about twenty times more surface than the other. See that both are thoroughly wetted and the indifferent electrode properly placed in position.

Moisten the skin of the part to be tested—place one hand on this part and with the testing electrode in the other apply it to the back of the hand holding the patient. Depress the key, causing the current to flow through the operator's hand to the patient. The strength of the current can be thus ascertained. The coil should already have been adjusted to give the strength of current usually employed. Note the contraction produced—if any—and whether it is obtained with stronger or weaker currents than normal. In testing with the constant or battery current, make the active electrode the kathode, and to commence with use sixteen cells (24 volts) for the limbs, and eight cells (12 volts) for the face. Note if a closing contraction is obtained—if not increase the number of cells, as soon as it appears, move the electrode about until point of maximum effect is obtained and then read the galvanometer. Now reverse the current and compare ACC with KCC. Note the character of the contraction—whether sharp and quick or slow and sluggish.

Compare contraction obtained by direct stimulation with that by stimulating its motor nerve trunk. If the disease is unilateral, compare the reactions of the sound side with those of the affected side. Finally test sensation with the induction coil current using the wire brush or bare metal electrode and the skin as dry as possible.

Changes in the electrical reactions.—As a result of disease, the electrical reactions shown by nerve and muscle may be modified in different ways. In the first place while the character of the response remains normal it may be obtained with a weaker or stronger current than usual. This is spoken of as simple increase or simple decrease of excitability. The amount or quantity of reponse relative to the current employed is different—hence these are called *quantitative* changes.

In the next place the character or *quality* of the reaction may be altered. These are *qualitative* changes and are of the greatest importance. Under this heading we have the reaction of degeneration, the myotonic reaction, etc.

Finally, all reaction to both coil and cells may be abolished.

Quantitative Changes.—Simple variations in excitability are not easy to be quite sure of, unless they exist to a considerable degree—owing to the difficulty in obtaining at all times exactly similar conditions in all parts of the circuit. The degree of moisture and thickness of the skin, the pressure of the electrode, and its position are all possible disturbing factors. Where the disease is unilateral the difference in the behaviour of the two sides is the best guide, but even here a difficulty arises in the fact that the skin of a paralysed limb sometimes has a much higher resistance owing to disturbances of nutrition. Fortunately the lesser degrees of quantitative change have little or no diagnostic value.

Increased Irritability indicates an increase of irritability in the central nervous system and is generally accompanied by increased reflexes. It is found in chronic myelitis and unilateral disease of the cord.

Decreased Irritability is more common. It is seen in mild degrees of anterior poleimyelitis and neuritis. Simple fatigue is said to cause diminished irritability.

Qualitative Changes.—A description of these changes practically resolves itself into a treatise on the reaction of degeneration—usually abbreviated to RD. When present it is always of the greatest importance. It is recognised by the fact that the response to the battery current is of a different quality or character to that seen under normal conditions. Instead of the sharp quick jerk, the contraction produced is slow and sluggish. It often happens that the anodal closure contraction (ACC) is more easily obtained than the kathodal closure contraction (KCC). At one time this was thought to be always present and to be the most important evidence of the presence of RD. This however is not invariably the case and it is now pretty generally agreed that in the slow, sluggish contraction, we have the surest sign of a muscle undergoing degeneration.

In a typical case of RD the muscle does not respond when its motor nerve trunk is stimulated nor will it respond to direct stimulation with the coil current. If the battery current is slowly made and broken it will respond but not if the interruptions be rapid.

In the early stage of RD it is often accompanied by an increase of excitability. Though the contraction is slow it is obtained with a weaker current than is required under normal conditions. Erb, to whom medical electricity owes so much, has formulated a definition of RD which should be committed to memory. "It is characterised by the dimunition and loss of 'faradic' excitability in both nerves and muscles, whilst the 'galvanic' excitability of the latter remains unimpaired, is sometimes notably increased, and always undergoes definite qualitative modifications."

The presence of RD having been found the question naturally arises—What does it signify? It means that there is a "break in the nervous link which connects the end plate of the muscle with its nucleus of origin in the grey matter of the anterior cornu of the spinal cord."

It is important to fix this in our mind, as it so accurately defines the limits between which the nerve lesion will be found in any case where RD is present. It follows any injury or disease of motor nerve trunks, of the ganglion cells in the anterior cornu of the spinal cord, or those of the nuclei of the cranial motor nerves. This includes peripheral neuritis, anterior polio-myelitis, acute and chronic, diseases of the cord accompanied by muscular atrophy, myelitis, lead poisoning and diphtheritic paralysis. It does not follow cerebral paralysis, except when the nuclei of the cranial motor nerves are involved, nor is it found in diseases of the muscle fibres themselves—idiopathic muscular atrophy.

It will be convenient here to study the series of changes which take place in a typical case, such as the complete severance of a motor nerve, the result of an accident.

At first there is a brief period of increased excitability in the nerve, which is quickly followed by a progressive decrease, so that by the end of a week or so its irritability is completely lost to both coil and battery current. These changes are due to the degeneration of the nerve trunk, extending progressively downwards from the point of division. In the muscle there is also the first brief period of increased irritability, followed by a progressive decrease to coil currents until it completely disappears. The increase of excitability to battery currents is maintained much longer—perhaps for six or eight weeks—but by the end of the first week the contraction begins to be sluggish, and very often ACC > KCC.

As the degeneration reaches down to the intra-muscular nerve fibres the muscle ceases to have any special motor point, so far as testing is concerned, and then it will be found best to place the active electrode on the end of the muscle close to its tendon, causing the current to traverse the muscle longitudinally. This stimulates the muscle fibres themselves, and gives a better contraction. In extreme cases it may be necessary to place one electrode at each end of the muscle before any decided contraction can be obtained. This is called the "longitudinal reaction." Cases which do not recover show a progressive dimunition of excitability until all reaction is completely lost. On the other hand, those which recover will sometimes show a return of voluntary movement before there is any improvement in the response to an electrical test—others will show a slight reaction to faradism as the first sign of a return to normal conditions—the contraction to battery current still remaining sluggish. Such a state of affairs constitutes what is often referred to as "partial RD."

Partial reaction of degeneration is an intermediate stage, and its significance depends largely on the past history of the case. A case shewing it for the first time indicates the existence of a nerve lesion, and that complete RD will be developed in the absence of early arrest or recovery.

Partial RD coming after complete RD is conclusive evidence of recovery taking place. This stage may often pass unrecognised unless the operator is careful to test every case with both coil and battery currents.

Prognosis.—In addition to giving an electro-diagnosis, the operator will be often asked his opinion as to the probable future history of the case. To give a prognosis on the result of the electrical examination alone would be extremely unwise, to say the least of it. Take a case of paralysis from cerebral disease—here the reactions are normal—the seat of the lesion being above that portion of the nervous system which comes within the scope of electrical testing. To give a favourable prognosis because reactions were normal would be absurd. Again, take the case of facial paralysis with RD present. One would scarcely give such a favourable prognosis if the paralysis were due to disease of the temporal bone, as in a case where it was due to exposure to cold.

So in all cases it is absolutely necessary to take into consideration the whole history of the case, remembering that electro-diagnosis only affords information regarding one part of the nervous system—"the lower segment." As for RD itself "other things being the same, the lesion is serious, the probable duration of the disease longer, the definite prospect of a cure more remote in proportion as the reaction of degeneration is developed and complete, and in proportion to the stage which it has reached."—Erb.

Among those cases which one may be called upon to pronounce an opinion, few present greater difficulties than that of ascertaining whether a nerve has been divided or only injured, as RD follows in either case. The changes following on a cut nerve have been given. Speaking generally, those following a severely injured or crushed nerve, are not so complete. Some muscle or part of a muscle may be found which still reacts to the coil current—so also the wasting or anæsthesia may be incomplete, and the general progress of the case is not so rapid as when the nerve is completely divided. Notwithstanding, all this, cases will arise which, if not impossible to answer positively, will tax the skill of the operator to its utmost.

The electrical examination of the muscles, supplied by a nerve which has been divided and sutured, it is not of much value—voluntary movement often returns before there is any great improvement in the electrical reaction. It is well to remember that in a case of division and immediate suture of a nerve under the best possible conditions, it will be from three to six months before the functions are completely restored. The longer the time between the injury and the operation for its repair, the longer does the process of regeneration take. Also the further the muscles from the seat of injury the greater is the time required for its return to normal power and reactions—consequently when a motor nerve is divided and sutured, of the muscles affected, those nearest the wound recover first and the distal ones last.

Though the time required is comparatively long, nerves retain their power of regeneration to a remarkable degree, so that, though the muscles supplied by a nerve which has been divided, may be greatly wasted, and all electrical reactions completely lost, owing to delay in suturing the divided ends, it is nearly always safe to say "it is never to late to mend"—or at least "to attempt to mend"—so long as the local conditions permit of such operation being done with a reasonable prospect of success. In such a case recovery would be very slow, if it took place at all, and perhaps incomplete. With the intelligent use of electricity and massage, much can be done to assist the process of regeneration, and even a partial return of function is much preferable to complete loss.

The electrical testing of sensory areas is not often called for since it provides no information which cannot be obtained by simpler means. Electrical sensibility, practically corresponds to pain sensibility so that the pin point does all that is usually required.

The induction coil current is always used for this purpose and for the active electrode, either a wire brush or a modification of it in which the wires are embedded in some insulating material so as to be separate from each other at the free end, and enclosed in a ring of ebonite—the whole being finished off smooth. The wires are all joined together at the other end where it is attached to the electrode handle.

Figure 60 shows this electrode, both side and end view, the latter is rather less than one inch in diameter and has

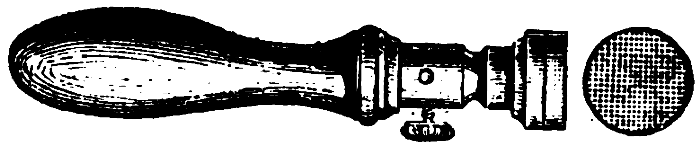


Fig. 60.

about 200 wires showing. The current enters the skin by so many paths, and the surface being quite smooth and polished it can be easily moved about, and the sensitive or insensitive areas mapped out. Another good method is for the operator to hold one electrode in one hand—the other being applied to the patient—and use the tips of the fingers of the other hand as the active electrode. He is thus himself conscious of the current passing, and if he has a switch under the control of the other hand and out of sight of the patient, the latter's statements can be easily checked.

CHAPTER VII

ELECTRO-SURGERY

THE surgical use of electricity is confined to the destructive action of the products of electrolysis on the tissues. Its great advantage lies in the fact that only so much of the caustic as is wanted is produced and it is made in the area where its effects are desired. The action is thus exactly localised and under perfect control.

It has been employed for the removal of superfluous hairs, warts, moles, destruction of naevi, strictures, and cancerous growths, in the treatment of fibro-myoma of uterus, and to produce coagulation in an aneurismal sac.

Removal of superfluous hairs.—To do this successfully a good light is necessary. The indifferent electrode—the anode—is placed on any convenient part of the patient's body. The other pole is connected to a fine platinum needle which is mounted in a handle as in figure 61.

Fig. 61. Epilation needle,

Four cells are placed in circuit and the operator studying the hair with the forceps introduces the needle into the follicle passing in the proper direction along side the hair. The needle enters from one-tenth to one-eighth of an inch. In about five seconds or so a slight effervescence is seen at the orifice of the follicle, and the needle is withdrawn. The hair should come out by very gentle traction. If not the needle may be inserted again for a couple of seconds

The point of the needle must not be too sharp. A dull point finds its way down into the follicle more easily. Platinum needles should always be employed and sterilised in the flame of a spirit lamp before use. There is a sharp stinging pain at the moment the needle is in the follicle, but it is not so severe that an anaesthetic is ever necessary. The local application of cocaine is useless unless introduced by cataphoresis ; even then it is scarcely worth while.

When a large number are to be removed, only from twenty to thirty should be done at a single sitting, and these should be removed from over the whole surface. If this number were removed from one spot a troublesome ulcer might result. The successful use of this method requires both practice and skill. Under the best conditions a certain number of the hairs return and have to be removed again.

Moles.—If small and hairy, epilation as above may be all that is necessary. With the removal of the hairs the mole shrinks and loses much of its pigment. If large and highly pigmented it had better be treated as an ordinary naevus.

Naevi.—Electrolysis is a most valuable method of treating naevi, and in some cases the only satisfactory one. With practice the operation is under perfect control and the results in suitable cases is all that can be desired. The object is to break up the blood vessels and coagulate the blood therein without causing general necrosis and sloughing. In short, the great thing is to know when to stop.

If the growth is subcutaneous, the skin is not to be interfered with in any way except for the minute openings where the needles are inserted. If the skin is also involved, a certain amount of scarring is unavoidable.

There are two chief methods of carrying this out—the unipolar and the bipolar methods.

Unipolar electrolysis.—A large indifferent electrode is placed on any convenient part of the body and connected to the positive pole. The needle or needles are attached to the negative pale and introduced into the naevus.

Fig 62 shows a holder with twelve needles, one or more of which may be inserted as required.

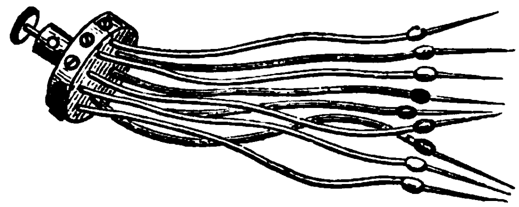


Fig. 62 Needles for electrolysis.

In a large naevus they should be introduced evenly through the mass, and the indifferent electrode must be very large and accurately applied. Where individual vessels can be recognized, the needle should be made to pass near, or even transfix them. Occasionally naevi of a stellate form are met with, where all the vessels composing it appear to radiate from a common point. In such a case one needle inserted at this point will in all probability cause the disappearance of the whole.

In all cases the current is to be turned on and off very gradually. The currents used are large and if the needles are suddenly removed without first lowering the current to zero a severe shock would result. The current should not exceed twenty milliamperes per inch of needle inserted.

The bipolar method is to be preferred in most cases and is best carried out by means of a bipolar needle holder devised by Dr. Lewis Jones and shown in fig. 63.

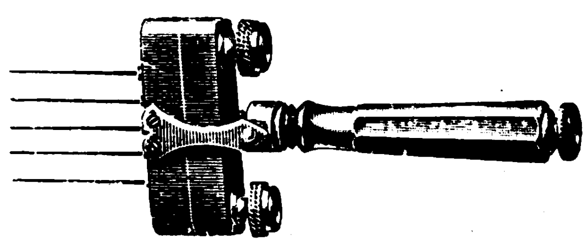


Fig. 63. Dr. Lewis Jone's bi-polar naevus needle holder.

The two wires from the battery are joined to the two terminals shewn. The internal connections are such that the needles are positive and negative alternately. Two, three, four, or five needles may be used according to the size of the mass to be treated. From four to six cells are turned on and then the needles are pushed through the mass. A galvanometer must be in circuit and the current not allowed to exceed the proper amount. Here again the needles should be of platinum and sterilised by heating to redness before use. Soon after the needles are inserted the tissues round them begin to change colour. Round the positives there is hardening and pallor and the needle tends to become fixed and difficult to withdraw. Round the negative there is frothing with hydrogen gas given off, while the needle itself gets very loose. The tissues tend to become dark and livid round the negative and on the first sign of this should be withdrawn and reinserted in a fresh place if necessary. In using this holder, Dr. Lewis Jones considers the current should not exceed twenty milliamperes per inch of *positive needle*, if sloughing is to be avoided.

Other variations of the above methods and appliances are advised and used but these given will be found quite satisfactory in nearly all cases. The pain is severe, and an anaesthetic is required in practically every case. For after-treatment a piece of antiseptic gauze is applied over the punctures with flexible collodion. If sloughing supervenes an antiseptic poultice is applied at first until the slough is cast off and the ulcer treated on general principles. Small naevi, not over one quarter of an inch in diameter can be destroyed at a single sitting. When larger than this, two or more will be necessary.

The aim should be to destroy the naevus, either completely or as far as possible, at the first sitting. As the tendency of most naevi is to increase in size they should be treated at the earliest possible time, and special attention should be given to the margin in all cases if recurrence is to be avoided.

It has been suggested to use copper needles in place of platinum, with the idea of despositing a salt of copper in the naevus. Good results are obtainable, but it does not appear to have a special advantage over the method usually employed.

In treating port wine marks, a single needle is used connected to the negative pole. The indifferent electrode positive, placed on the sternum or other convenient part. The needle is inserted into the skin vertically and a current of three to four milleampres passed for a short time. The area must be treated in a number of sittings—the needle at each sitting being introduced at various points scattered over the surface as is done in removing superfluous hairs. Cocaine may be introduced by cataphoresis beforehand if the pain is too severe.

Aneurism.—The treatment of this condition by electrolysis has not been satisfactory. The best results in this country have been obtained by the late Dr. John Duncan of Edinburgh. It is only applicable in cases where ligature is impossible or attended with special risks. The great objection to the method is the necessity of piercing the wall of the sac with the risk of setting up hemorrhage. The needles must be insulated except at the points, so that no bare metal comes in contact with the sac during the passage of the current. Both positive and negative needles are introduced into the tumor and large currents and long sittings are the rule.

The whole aim of the treatment is to set up clotting of blood in the sac, but unfortunately the clot produced by electrolysis is soft with no special tendency to harden and organise into fibrous tissue.

This form of treatment is indicated in thoracic and subclavian aneurisms where medical treatment has failed.

Strictures.—Very little has been heard of the electrolytic treatment of strictures during recent years. It offers no very decided advantages, and if sufficiently strong currents are used to produce active electrolysis, it is attended with some danger. A large indifferent electrode is placed on any convenient part of the patient's body, and is connected to the positive pole. The active electrode consists of a catheter—shaped bougie, terminating in a bulbous enlargement. The latter is left bare, and the stem is covered with insulating material—the whole being more or less flexible. One is shewn in fig. 64.

At the outer end is provided a terminal for attaching it to the negative pole. The size of the largest bougie that will pass the stricture as well as its distance from the meatus, having been ascertained, a bougie electrode is selected two sizes larger, and a mark made on its shank corresponding to the distance of the stricture from the meatus. It is now passed down to the stricture against which it is held, but no force is to be used under any circumstances. The circuit is closed and the current gradually turned on until five or six milleamperes are passing. The pressure on the bougie must be gentle, and in the direction of the urethra, otherwise a false passage may be made. This is kept up until the bougie passes through the obstruction and into the bladder when the current is to be at once gradually reduced to zero and the instrument removed.

This operation may have to be repeated at intervals of not less than three weeks.

Another method is that of "linear electrolysis." The active electrode consists of a long, flexible bougie, in the middle of which is a projecting blade of platinum (not sharp). This blade is connected to a terminal at the outer end. The leading end is filiform and serves as a guide. The instrument is introduced, and the blade pressed against the stricture. The current is gradually turned on until 10 milleamperes is reached which is sufficient in most cases.

The method is one of what might be termed "electrolytic incision." The instrument is pressed against the stricture until the latter is divided, which takes place in about thirty seconds. Strictures in other parts, such as the lachrymal duct, eustachian tube, oesophagus, and rectum, have been treated by electrolysis with more or less success. The method differs in no essential particular from those given for stricture of the urethra.

Electrolysis has also been successfully employed in the treatment of goitre, exophthalmic goitre, cancer, and uterine fibroids. A great deal has

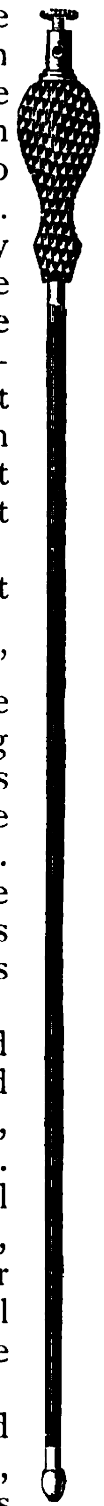


Fig. 64. Bougie Electrode.

been written for and against this treatment uterine of fibroids since Apostoli published his method in 1882.

The action is to destroy the uterine mucous membrane which resulted in a reduction of the size of the uterus and decrease of hemorrhage. The most that can be gained in the great majority of cases is of a palliative character.

Apostoli used an internal positive electrode of platinum, and an indifferent electrode of moist china clay, and a current of from fifty to eighty milleamperes passed for from five to fifteen minutes. The method is not much employed now.

The Electric Cautery is of course not an instrument for electric treatment. The part played by electricity is merely that of a convenient means of heating the burner, enabling it to be introduced into a cavity or other part while still cold, and brought to a proper heat while in position. For a full description a larger work should be consulted or one of the text books on surgery.

CHAPTER VIII

General Therapeutics.—Rockwell in his exhaustive work on the subject describes the action of electricity in therapeutics as "a stimulating sedative tonic." In doing so he is careful to state exactly the meaning he attaches to the terms used.

A stimulant in the sense that it corrects, intensifies or economises the forces of the system. A sedative in that it tends to allay irritability and pain and to induce natural repose, and a tonic because it gradually improves nutrition, restores enfeebled functions, invigorates the system as a whole and permanently increases its capacity for labour. It is important to emphasise the fact that electricity is not a stimulant in the sense in which that term is frequently used, viz:—an agent which will temporarily rouse the system to increased activity with or without subsequent exhaustion. While surprisingly rapid results are sometimes obtained from a local application in certain cases, its action as a general therapeutic agent is not of this kind. It resembles other tonic agents in this; but differs from them in possessing valuable properties peculiar to itself.

Its action on contractile tissues has been already gone into. It is a stimulus to nervous tissues, and through them the vaso motor system, resulting in relief of congestion and pain and stimulating all the tissues to increased activity. These effects are seen in the treatment of rickets, anaemia and general debilitated conditions. Such patients, as a result of a course of some form of general electrization, are found to benefit in a marked degree—appetite, digestion, sleep.

and general appearance are all improved. For local conditions it is of great benefit in cases of injured or diseased nerves, wasting of muscles and the relief of pain. Its destructive power may be used for the removal of *naevi*, moles, or other small growths and the removal of superfluous hairs by electrolysis and its osmotic or cataphoretic properties, already referred to, seem likely to become of great importance.

The particular form of electricity used will depend on the requirements of the case or the effects desired.

If a stimulating effect is wanted—either local or general—we must use some form of varying current such as induction coil, simple alternating or sinusoidal current. In the treatment of paralysed muscles the rule has been that if the muscle will contract to the coil current it should be used, if not, then the constant current. Recent investigation, however, shows that equally good results are obtained by both methods. Probably if the variable current is used one having a low frequency is to be preferred.

For treating deep seated organs the constant current or a very slow rythmic, or sinusoidal current should be used, and the electrodes should be placed far apart. Rapidly varying currents are not so useful on account of their slight penetration.

As a local sedative the constant current is the best and the anode should be the active electrode in such cases.

The indications for the use of static electricity and high frequency currents have been given under their respective headings.

Dosage.—Like any other therapeutic agent, electricity must be administered with care and discretion. Under ordinary circumstances there is no need to employ currents of such strength as to cause actual pain.

With the coil the operator should try it on himself and note the adjustment of the secondary coil or core to give certain effects. By always, as far as possible, using the same apparatus he will know very nearly the strength of current the patient is receiving.

It should be an invariable rule in electrical treatment never to turn the current on or off suddenly. This is specially necessary in using the constant current where neglect of this precaution might give severe shocks, with regrettable results. The patient's circuit should be closed with the adjustments at zero, and the current gradually turned on. In the use of the constant current the milleamperemeter is the guide to dosage. It should be so placed as to be in view of the operator and its indications watched. Constant current apparatus of any kind should be most carefully made and maintained in perfect order. A loose connection for instance may give rise to severe shocks if the apparatus receives a silght knock or jar during the application of strong currents, and if the head or neck happened to be the part under treatment, the most serious results might occur. Apart from the question of any real danger to the patient, the latters confidence may be lost, and this is usually followed by a loss to the operator!—a point always worthy of consideration in private practice. The strength of constant current for local applications varies from five to ten milleamperes. Larger currents may be required at times, when larger electrodes must be used so that the current density is kept low.

As to the length of applications, they should be long enough to produce useful effect but not so long as to cause over stimulation and consequent fatigue which might do more harm than good. From ten to fifteen minutes is sufficient for each application and may be repeated from two to three times per week under average conditions.

If continued for at least one month it will be possible to form some idea as to whether it is likely to be worth while going on. As has been said already the results of electrical treatment are developed slowly.

At one time some importance was thought to attach to the direction of current and "ascending" and "descending" currents were spoken of. It is difficult to see how the direction of flow in the interpolar area can have any influence on the results since the effects take place at or near the poles.

It is more usual now, and more correct to speak of treatment by the positive pole (anode) or negative pole (kathode)

—the active electrode being the one referred to. This brings us to the question of the choice of pole.

This question can only arise when it is proposed to use the constant current or one which is at least unidirectional, viz., the simple interrupted, rectified alternating, and the "primary," or self-induction current, from an induction coil.

Properties of the two poles :—

Anode—

Anaesthetic, sedative.—Drying, depleting, and haemostatic, is capable of diffusing certain medical substances through the body. Electrolytically, is less destructive than the kathode.—Acids, chiefly hydrochloric, and oxygen gas are liberated.

Kathode—

Stimulant.—Increases moisture and quickens absorbtion. Dilates blood vessels and canals—congestion. Is capable of diffusing certain other substances through the body. Electrolytically is the more destructive pole—Alkalais, chiefly caustic soda, and hydrogen gas, being set free.

Should the student find any difficulty in remembering the properties of the two poles correctly, it may be a help to always think of the positive pole as the "Acid, Anæsthetic Anode." This gives the reaction of the electrolytic product, and the chief effect of the anode when used locally. The properties of the kathode are the reverse.

Of course in any application the two poles must be applied to the patient and each pole produces its own proper effect, but whichever one is made the indifferent electrode this effect is spread over such a relatively large area that the result is a negliable quantity. From the above, it follows that the anode would be selected for use in painful conditions, while for stimulating paralysed muscles, or provoking muscular contractions in electrical testing, the kathode is used.

The methods of application employed in electrical treatment vary with the circumstances of the case and with the particular form of current used. The special methods and apparatus required in administering static and high frequency currents have been indicated in a previous chapter. All the other forms of electricity are applied by means of ordinary electrodes.

The most common method is that of a large indifferent electrode placed on some distant part, and a smaller or active electrode applied to the part it is desired to treat. A basin of clean warm water is required for each patient. In this the electrodes are to be well soaked and the skin over the part to be treated is also moistened. The size of the active electrode is regulated by the extent of the area to be treated and the strength of current to be used. Several sizes will be required from two to four inches in diameter—even larger ones may be sometimes necessary. The active electrode is first applied to the part and the current gradually turned on. It is kept in one place (stabile method) or moved about over the whole area (labile method). In treating facial neuralgia the anode used, stabile, would be employed. For a paralysed muscle the kathode, labile should be used. The effect of the latter so far as any particular part of the area treated is concerned, is that of a slowly but constantly varying current.

If it is desired to concentrate the current in any part, the two electrodes are brought near together.

Under all circumstances keep the electrodes well wetted, particularly when used labile. A little soap on the surface of the active electrode is a great help.

If muscular contractions are desired, the current may be interrupted by the closing key on the handle, or it may be reversed by means of the reversing switch on the battery. The latter method is the more powerful and is very effectual in stimulating unstriped muscle.

A most useful method of applying electricity is through the medium of water. Arm baths and leg baths are now procurable and will be found most useful. The advantage of water lies in its perfect adaptation to the part immersed, and the skin resistance is reduced to the lowest point.

An arm or a leg may be immersed in a bath connected with the indifferent pole—constituting a large, perfectly fitting, indifferent electrode. Or the affected limb may be immersed as well and the current applied in this way. The electrodes consist of plates of carbon, or metal, hung over the edge in any convenient position. They are pro-

Fig. 65. Arm Bath.

vided with a bindings crew to attach the wire from the battery. This is specially valuable in treating paralysis of the muscles of the arms and legs, Raynaud's disease, chillblains, gout, and rheumatoid arthritis, and the treatment is greatly simplified in that an assistant is not required for each patient to move the electrode about.

The arrangement in which one electrode is applied to each bath is called the monopolar bath. All the current entering the bath goes through the patient and can be measured. If both electrodes are put in one bath or trough, the arrangement is called a di-polar bath. In this case, part of the current passes through the water without touching the patient, and the amount going through the body or limb immersed can only be guessed at.

Monopolar baths are largely in use in hospital practice. Figure 65 shows a case being treated in this way.

The current is regulated by the sliding shunt resistance and galvanometer, while moving a small double-armed switch close by makes the current supplied to the board constant or sinusoidal as required. Instead of two arms, an arm and a leg may be immersed or both arms and both legs.

The most highly developed form of the monopolar bath is that designed by Dr. Schnee which is shown in fig. 66.

It consists of a large chair, in which the patient sits, provided with four troughs or buckets in which carbon electrodes are secured, and a switchbound board of special design. The regulation is by means of a shunt resistance. In the lower part is a small motor, on the shaft on which are mounted a series of commutators and brushes. An adjustable brake is provided to vary the speed of the motor.

Constant, interrupted, or alternating current is obtainable, and by means of plugs any bath can be made positive or negative. There are some forty or fifty different arrangements by which the current can be made to traverse the patient. It is a very useful appliance. In the electrical department at the London Hospital one has been in use for a considerable time, and has given much satisfaction. It has been used with some success on the Continent in the treatment of gout and rheumatism. The special feature was that of dissolving salts of lithium in the water in the vessels, and introducing the substance by electric osmosis. The method has not been sufficiently tried to yet form an opinion of its real value.

Fig. 66. Dr. Schnee's Bath.

The bi-polar bath—in which both electrodes are immersed in the same vessel of water—is made of some insulating material as wood, fibre, porcelain or earthenware.

A small size is useful in treating the hands or feet for Raynaud's disease or chilblains. The patient can control the strength of current with the greatest nicety. If the case is one of chilblains of the fingers, he places his two hands together, and immerses them in the water—the current being already turned on—midway between the electrodes. Practically nothing will be felt. The hands are slowly separated and the current is felt to get stronger as the electrodes are approached.

As a means of applying electricity to the whole body the electric bath is the most agreeable and most efficient method we have. Large electrodes are placed at the head and foot, and the bath filled with water at a temperature of from 98° to 100° Fah., so as to cover the patient's shoulders when in the bath.

The electrodes should be of metal and kept clean and bright. They should be 12″ × 18″ for the head, and 12 × 10 for the foot. A paddle electrode connected to one of the others is sometimes used by the operator to concentrate the current on any required part. A back rest made of a wooden frame with strips of webbing stretched across is required for the patient to lean against, and keep him from contact with the electrode. A similar one may be required for the foot. They should be made to fit the bath in which they are used, or they will give trouble. Fig. 67 shows the bath in use. In this particular one, constant "fa·adic" or sinusoidal current can be employed as required. In this full bath treatment, more than ever has one to be careful how the current is turned on or off. Anything approaching a sudden alteration in the magnitude of the current must be carefully avoided. No current is to be turned on before the patient is in the bath. It is then slowly and gradually raised to the required strength, which is determined by the patient's sensations as much as anything. It must not be so strong as to cause pain or discomfort. Using constant current in the bath here illustrated, the total current varies from one hundred to three hundred milleamperes.

The current is left on for about ten minutes, when it is turned off in the same slow and gradual manner as it was turned on at the beginning. The amount of current actually passing through the patient will depend on the relative sizes of the patient and the bath, and the extent to which the latter is filled. Under ordinary conditions the patient receives from ten to twenty per cent. of the total current. The rules for the choice of current are the same as those already given in a general way. In those conditions in which pain is a prominent feature such as

Fig. 67. Electric Bath—bi-polar.

neuritis, sciatica, rheumatoid arthritis, rheumatism, etc., the constant current is to be preferred. When stimulating effects are wanted, a constantly varying current is more suitable, such as the faradic, or sinusoidal. The latter is the more preferable except where it is wanted to stimulate contractions in muscular tissues. The paddle electrode is useful here to concentrate the current where required.

Fig. 68. Paddle Electrode.

The secondary winding of a coil for bath purposes should be made up of a small number of turns of coarse wire. The voltage required is small—about six—but the magnitude of the current should be large.

To use the sinusoidal current from the main, a shunt resistance or transformer may be used. Another way is to use an ordinary sledge coil. The platinum contact is first screwed down so that the spring cannot vibrate. The sinusoidal main current is supplied to the battery terminals of the instrument through a lamp resistance. The bath electrodes are attached to the secondary terminals, and the strength of current adjusted by gradually sliding the secondary over the primary. This method is both safe and efficient. For constant current bath treatment the safest way is to use a battery of large Leclanche cells or accumulators. The constant current from the main may be used provided certain precautions are taken. The danger lies in the possibility of leakage to earth from the main conductors through the patient, and this danger is greater the higher the voltage of the supply. The modern tendency is to supply at as high a pressure as is allowable. To prevent such an accident, which might be fatal, there are two courses open—the bath is to be either thoroughly insulated or thoroughly earthed.

To thoroughly insulate the bath is practically impossible in the case of those already fixed, but it is quite feasible if the bath is installed with that end in view. The one at the London Hospital was done this way and is satisfactory. The bath itself is of porcelain. Large rubber pads about one inch thick are placed between the bath and the cement pedestals upon which it rests. Part of the waste pipe consists of a length of rubber hose—leakage may occur here along the thin layer of water left in the pipe, but its resistance is high enough to prevent any leakage worth troubling about. The water pipes are kept clear of the bath and discharge from a point high up out of the reach of the patient.

Dr. Lewis Jones considers that "no method which depends for its safety upon the maintenance of insulation from earth of a bath containing water is good enough to risk," and certainly as regards the use of baths already installed in the ordinary way it is safest to do as he suggests, and make sure it is well earthed by its waste-pipe—connecting it by a soldered-on wire to the cold water pipe if necessary. The current is regulated by resistances in series with the bath—one resistance between each electrode and the main current. If a sliding shunt resistance is used there should be a safety lamp at each end of the shunt. No one, not thoroughly conversant with the subject, should attempt to use the current from the main for hydro-electric baths under any circumstances.

The first sensation of a constant current bath is that of burning or pricking at the ankles or knees, and as the current becomes stronger a metallic taste will be noticed. If the patient feels faint the current must be reduced. The bath must not be given soon after a full meal.

If langour or depression follow the bath it means the current has been too strong. The patient should dress slowly so as to cool off gradually and rest for a quarter of an hour or so before going out into the open air. There is no special liability to catch cold after an electric bath particularly if the patient walks home, which he should always do if possible.

At least twelve baths are required to produce a satisfactory result—but many cases arise in which it is found necessary to give a great many more. In no form of electrical treatment is it more necessary to exercise the utmost care than in everything pertaining to the electric bath; what would be of more or less trivial account under other conditions, becomes a serious matter here. Any sudden change in the magnitude of the current, however small, has a very alarming effect on the patient. This is not unreasonable considering how helpless he is when immersed in the water, and so placed that small changes have as much effect as large ones under other circumstances. Binding screws, conducting cords, and the slider of the regulating resistance are all sources of trouble. They should be frequently inspected and tested, and all the arrangements should be personally examined by the medical man before each bath is given. He should turn the current on himself and not leave the room until he has turned it off, before the patient comes out. For female patients a bathing dress is necessary, as is also the presence of a nurse or maid in the room. The electric bath is a most valuable method of application—as a means of "general electrization" it is the best at our disposal, and the one most frequently used in this country. In America, "general faradisation" is the more popular method, while the electric bath is apparently used to only a limited extent. This is a striking instance of the difference in the usual practise of the two countries.

General Electrisation.—This term is applied to any method which has for its object that of placing the whole body under the influence of electricity in one or other of its forms, so far as practicable.

It may be carried out by means of the electric bath, by static electricity and by high frequency currents. These have all been described.

It may also be carried out in other ways such as "general faradisation." This method is very fully described and illustrated by Rockwell of New York in the last edition of his work. The patient stands or sits on a large metal plate which is covered with moist flannel, and if necessary kept warm by a hot-water bottle. One wire from the induction coil is attached to this plate, and the other to the active electrode. This may be one of the ordinary kind or a sponge used directly on the patient, or else held in one hand by the operator who uses his other hand as the active electrode. It is moved over the head, neck, back, abdomen, arms and legs—from two to three minutes being given to each. The strength of current is not so strong as to be the least unpleasant. It is not necessary to remove the underclothing. A pleasant feeling of vigour follows with relief of fatigue, and improved appetite and ability to sleep. There is no doubt as to the great value of the method, and is the one to employ whenever the electric bath is not practicable.

The faradic current may be used alone or in combination with the galvanic or constant current. This was suggested by Dr. de Watteville and called by him "galvano-faradisation"

It has the effect of giving increased volume to the faradic current, and the refreshing action of the galvanic tends to counteract any bad effect of over-stimulation by the faradic current. Its employment is very much a matter of custom or fashion.

Central Galvanisation.—This is also a favourite method of electrical treatment in America and is spoken of very highly by Rockwell. As he describes it, the object in central galvanisation is to bring the whole central nervous system—the brain, sympathetic and spinal cord—as well as the pneumogastric and depressor nerves under the influence of the galvanic current. One pole (usually the negative) is placed at the epigastrium while the other is passed over the forehead and top of the head, by the inner borders of the sterno-clido-mastoid muscles, from the mastoid fossa to the sternum, at the nape of the neck and down the entire length of the spine." The active electrode is first applied to the forehead, moving it from side to side for two minutes, then to the vertex—first wetting the hair—stabile for one minute or at the most two. Here the current must be gradually turned on and off while the electrode is in position. The electrode is then applied down the inner border of the sterno mastoid, from the mastoid to the clavicle, both sides, for from one to five minutes.

It is then applied to the cervical vertebræ labile for about three minutes, and lastly to the whole length of the dorsal and lumbar spine for about five minutes. The current must never be so strong as to be disagreeable to the patient. That applied to the head and neck will be from five to ten milleamperes, and to the spine from ten to thirty milleamperes. It is stated to be very useful in those diseases which would seem to be due to a state of exhaustion and irritability of the central nervous system such as hysteria, chorea, neurasthenia, epilepsy, neuralgia and even some forms of insanity. The subject is treated in a most complete way by Rockwell in the last edition of his work "Medical and Surgical Electricity," and should be referred to by those wishing to enquire further into this form of electrical treatment. So far as can be ascertained, it has not been employed to any great extent in this country. The method is worthy of further investigation.

Subaural galvanisation—sometimes called "galvanisation of the cervical sympathetic," is not much practised now, although at one time it was thought necessary to carry it out in every case where it was hoped to act on the circulation and nutrition of certain parts of the brain.

The method is to place the cathode, an electrode of medium size, under the ear and a large positive electrode over the lower cervical and upper dorsal vertebræ.

It is a form of general electrization where by improving the circulation of the nerve centres it is hoped the whole organism will benefit.

In most cases where it is desired to favourably influence general morbid conditions some form of stimulating electrical application is indicated—such as the sinusoidal bath. It is specially helpful in treating those conditions due to deficient metabolism which are frequently accompanied by a decrease in powers of absorption and elimination.

In those conditions in which pain is a prominent feature, the constant current is most useful, placing the anode near the sensitive parts. Other disorders which seem to depend for their origin on some faulty state of the central nervous system, either central galvanisation or possibly subaural galvanisation, would be a suitable form of treatment.

A consideration of these principles will indicate the form of treatment most likely to be of use in any given case.

CHAPTER IX

SPECIAL THERAPEUTICS

Cerebral diseases.—The electrical treatment of these disorders has been somewhat neglected of late years, due probably to fear of unpleasant effects during treatment and to a belief that it was incapable of doing any good.

In skilled hands the application of electricity to the brain is without danger or discomfort, and it is not true to say that it has no power to do good in such disorders.

In all cases of this kind it is the constant current that is used and the greatest care is to be taken not to cause any sudden change in the magnitude of the current while the patient's head forms part of the circuit. Induction coil and other rapidly varying currents are not well borne, except in such small magnitudes as to be of no use so far as the interior of the skull is concerned. The shape of the head lends itself very readily to the diffusion of the current and it may be stated that it is more or less impossible to influence one part of the brain more than any other.

The aim of galvanisation of the brain is to improve the circulation—correcting anæmia or congestion and so improve its nutrition.

If it is desired to stimulate the flow of blood through the brain the kathode is placed on the forehead and the anode on the nape of the neck—whereas to relieve congestion the position of the electrodes is reversed. In negative applications we have a means of counteracting the effects of mental overwork and of stimulating mental capacity.

Mental diseases.—The cases most likely to benefit are those of melancholia in adolescents and mental apathy.

These are often accompanied by failure of general nutrition. The method employed was a course of sinusoidal baths. and the results were so good that it should be always tried. The general effects were a complete, or nearly complete, relief of mental symptons and a progressive gain in weight. Apparently these good results were due to the improvement in general nutrition—the brain benefitting indirectly.

Insomnia.—At one time or another a tendency to sleep is observed to follow any of the methods of general electrization. The author has observed it after the hydro-electric bath, static charging, high frequency treatment, and central galvanization. That it should be tried and not found wanting in the treatment of insomnia was only what one had a right to expect. All these forms of general electrization are indicated, but all will not be found suitable in every case. The cause should be carefully investigated and removed if possible. Static charging has a tendency to raise blood pressure, while that of high frequency is to lower it. Consequently a subject with high arterial tension should be treated with high frequency and vice versa.

The most generally useful method is that of the sinusoidal bath.

Hysteria.—In the treatment of this condition electricity has a value which is suggestive or psychic rather than curative. It is very useful to remove symptoms at times but does not always remove the cause. The moral effect is very useful where there are symptoms of spasm, paralysis, anæsthesia, and aphonia, and here treatment by sparks from a static machine is indicated.

High frequency currents are not to be used; the effect being that of making them worse almost invariably.

For the general condition, the electric bath and static charging with head breeze are at times very efficacious.

Spasms and tremors.—If these are due to organic disease in the nerve centres, such as paralysis and hemiplegia, electricity is not likely to do any good. Other forms sometimes do well with central galvanization.

Chorea.—Static electricity has been of much service in this complaint. The patient is placed on the insulated platform and sparks drawn from the spine and affected limb, using a ball electrode. This method of treatment was employed with great success since before 1850. In spite of this it is not much practised now. With modern static machines, as good results might be obtained by the use of the negative breeze which would be much more comfortable for the patient. The electrical treatment of chorea is worthy of more extended use.

Occupation Spasm.—For this group of affections—of which "writers' cramp" is probably the best known example—electricity has been tried but has not given brilliant results.

The constant current monopolar bath is the most useful application. It should be given twice daily for the first few weeks, gradually diminishing afterwards to two or three times a week. Absolute rest from the occupation producing the spasm is essential during the treatment.

Exophthalmic goitre.—Though the use of of electricity in the treatment of this condition, is quite empirical, a considerable number of cases do well. Mr. Cardew has reported cases in which the constant current has produced very great improvement in the general as well as the local condition.

The method is almost the same as that for subaural galvanization. The anode is placed at the back of the neck, while the kathode is applied to the side, labile from the mastoid process to the clavicle. Both sides are to be treated for six minutes each—the current from two to three milleamperes. It is best to teach the patient to make the application herself. It should be done twice or three times a day—and always when palpitation comes on, and persisted in for at least two months. Small batteries—fitted with dry cells—complete with electrodes can now be obtained for this purpose, and are very inexpensive.

Hemiplegia.—Some good can be done here, especially in the milder cases. No treatment by electricity is to be attempted during the first month after the onset, for fear of setting up fresh mischief in the brain. Central galvanization is to be employed, passing the current through the brain by different diameters but always so as to bring the seat of the lesion in a straight line between the electrodes. The object being to improve the circulation and facilitate the absorption and removal of the effused products.

For the limbs the faradic brush should be used over anæsthetic areas, and the muscles are treated best by monopolar baths and faradic or sinusoidal current. A large number of cases do very well for a time at least. After a while the improvement ceases and very little can be done afterwards. Complete restoration is of course impossible but as a certain amount of improvement is the rule the patient should always have such benefit as electrical treatment is capable of giving.

Other conditions which are greatly benefitted by electrical treatment are delayed convalescence, functional nervous diseases generally, results of influenza and post-diphtheritic paralysis. Some form of general electrization is indicated such as the sinusoidal bath, the details of the application being more or less modified according to the circumstances of each particular case.

There are some diseases of the spinal cord in which it seems almost entirely useless to attempt to benefit by electrical treatment. This is specially true of lateral sclerosis, myelitis, locomotor ataxy and also progressive muscular atrophy. Functional affections of the cord as well as anterior poliomyelitis and affections of the peripheral nerves are on quite a different footing in their respect, and as a matter of fact it is the exception for a case of one or other of these not to improve more or less under a proper course of electrical treatment.

Paralysis.—Of all the symptoms which may be present in the cases one is called upon to treat electrically, perhaps no one is more often present than that of paralysis.

In dealing with this symptom our efforts must be brought to bear on every part that is in any way responsible for the condition. The seat of the lesion causing the paralysis should be treated, whether it be in the brain, spinal cord or motor nerve trunk, in the hope of settling up beneficial changes there. The affected muscles must be treated so as to improve their nutrition, and also by acting on the sensory nerves to cause reflex impulses to be sent along the nerve trunks to the paralysed muscles. In treating with the constant current the anode should be placed over that part of the spine where the lesion is supposed to be, or over the nerve trunk, and the cathode is applied labile over the affected muscles. If a sinusoidal current of low frequency is available the monopolar bath may be used and so save the trouble of manipulating the electrode.

The induction coil may also be used with good results. All forms of electrical stimulation are useful in treating paralytic conditions, and since the induction coil is obtainable anywhere there is no excuse for not giving every case of paralysis the benefit of electrical treatment.

As a further aid to treatment, massage should be given to the damaged muscles daily, and also means should be taken to keep the part as warm as possible. The massage can be done at home and consists in rubbing and kneading the muscles for about fifteen minutes. For warmth extra covering is needed, in the winter time especially, which may have to be worn at night as well as in the day. The strict observance of such details is a great help towards recovery.

Infantile Paralysis.—This is the most common form of paralysis met with in the electrical department of a hospital, and fortunately is one for which a great deal can be done. The seat of the injury is in the anterior cornu of the spinal cord, and consists in a more or less extensive destruction of the ganglion cells. Owing to the fact that the nucleus of origin for any muscle extends through some length of the cord, it is impossible for any localised lesion to paralyse any single muscle exclusively, and, also especially if the lesion is small, is it unlikely that any large muscle will be completely deprived of the influence of nucleus of origin. Part of its nucleus may be destroyed while other parts are less damaged or even uninjured.

The idea that the ganglion cells are either destroyed or uninjured—rendering treatment futile in the one case, and unnecessary in the other,—is a most pernicious one. The everyday experience of those engaged in treating large numbers of these cases, as in the electrical departments of the large hospitals, is a direct refutation of it. No case is so extensive or so severe but that some good will result from proper and persistent treatment.

The state of the muscles in any case will depend on the severity of the original attack and on the time that has elapsed before coming for electrical treatment. It may vary from slight weakness without wasting or loss of voluntary power to complete paralysis with wasting and loss of response to all electrical or other stimuli. Different degrees may be found in the same case, and while the milder cases tend towards spontaneous recovery, it may be safely claimed that without electrical treatment the recovery is slower and less complete. In the more severe cases where there is wasting and reaction of degeneration, the tendncy to spontaneous recovery is very slight, but here electricity is able to do a great deal to improve matters. The secret of success in treating this condition is not so much the particular form of current used as perseverance in the treatment and attention to details such as massage, exercise of the muscles by proper movements, warmth, and encouraging the patient to make every effort to use the muscles for a few minutes every day. The method of applying the current varies with the seat of the paralysis. If it is in the legs or even one leg the double leg bath may be used or the child may sit in a foot bath of wood or other non-metallic material, sufficient warm water to cover the legs is to be added beforehand and a metal plate hung over the edge at each end which dips in to the water. The current is to be turned on gradually and must not be so strong as to make any of the muscles rigid. This should be carried out at home and the mother or nurse instructed in all the details of the treatment. The case should be seen at intervals of a month or so and the condition noted and compared with previous examinations. The electrical reactions will afford a good guide as to the progress of the case. In the most severe cases where at the beginning no reactions of any kind could be obtained, the first sign of improvement may be a very weak sluggish contraction---but more often there is a return of voluntary power with improvement in the local circulation before there is any return of electrical reactions.

Infantile paralysis affects the lower limbs more than the upper and the group of muscles suppled by the external popliteal nerve more often than the other muscles of the lower extremity.

In the upper extremity the muscles of the shoulder and arm are most often affected.

It is of little use commencing treatment of infantile paralysis unless prepared to persevere for at least six months, and most cases will require considerably longer.

Progressive Muscular Atrophy.—The electrical reactions in the myelopathic form of this disease are apt to be confusing. With the gradual degeneration of the ganglion cells in the anterior cornu the corresponding muscle fibres degenerate with the result that degenerated and undegenerated fibres are found side by side in the same muscle. The reactions are consequently mixed to the battery current—that is, a quick contraction followed by a slow one may at times be detected.

In the myopathic form the quality of the reaction is not altered, along with the atrophy is a simple diminution in quantitative reaction.

The electrical treatment of these conditions is not satisfactory, though it appears that cases treated in the early stage by galvanization of the cervical spine, cervical sympathetic, lumbar enlargement and peripheral nerves, have been much improved and even arrested. Faradisation of the muscles was also employed in the cases recorded. In this disease, as also in locomotor ataxy and myelitis, electricity seems powerless to effect a cure, but in some cases, in which it has been employed—spinal galvanization —there has been some improvement in symptoms, and possibly arrest of the progress of the disease. For this reason the use of electricity as an adjunct to other methods of treatment would seem quite justifiable.

Peripheral Nerves.—The value of electricity in hastening recovery after injury or disease of the peripheral nerves is now very generally accepted. Though it is maintained by some that the cases would recover quite as rapidly without treatment, many arise which have remained stationary for a considerable period of time before electricity is applied, and then begin to improve rapidly. Injury of the nerve trunks are most common in those placed superficially; and the injury may be of any degree from numbness, the result of slight pressure, to bruising, laceration and division with loss of motor power and sensation in the localities supplied by the nerve or nerves implicated.

They occur more often in the shoulder and arm, and all cases are most interesting from the diagnostic standpoint. Falls, blows, dislocations, pressure as from the use of a crutch, or falling asleep with the arm over the back of a chair may produce a musculo-spiral paralysis. Incised wounds about the wrist from broken glass or other cause frequently result in division of the ulnar or median nerves. The first thing to be done in any case of division is to find and suture the divided ends—or if the paralysis is the result of pressure by cicatricial tissue or callous it must be freed from its surroundings. The case will be referred for electrical treatment at a later date, and if tested, reaction of degeneration will be found in the muscles supplied by the injured nerve. The series of changes have been given in a previous chapter. Along with these changes there is an alteration in the nutrition, such as patches of congestion, oedema, clubbing of the fingers, and in the most severe cases a "wooden" condition of the parts due to interstitial oedema.

The condition to be treated in any injury or disease of peripheral nerves may be stated in the general term neuritis. The choice of current or method depends very largely on the acuteness of the symptoms and the amount of pain present. In neuritis we may have pain and paralysis separately or together. In painful cases the soothing properties of the constant current are best, changing to a low frequency sinusoidal and finally the induction coil as the pain lessens and the paralysis improves. For paralytic cases the sinusoidal or coil current may be used from the beginning. No method of applying any of these currents is superior to the electric bath in one or other of its forms.

Neuritis of gouty, rheumatic or alcoholic origin as well as that due to metallic poisions, and septic or specific disease is always benefited by a course of electrical treatment.

In any given case of peripheral neuritis in a motor nerve there is always more or less paralysis associated with it. These peripheral paralyses form a large portion of the cases sent to the electrical department of a large hospital for diagnosis and treatment. There are a variety of forms, depending not only on the particular nerve or nerves involved but also on the seat of the lesion in the course of the nerve. It is impossible to go into them all in a work of this size and only the most common forms will be alluded to. For the other forms the larger works should be consulted.

Facial Paralysis.—This may be of central or peripheral origin—the latter being the more common.

The nerve passes through a close fitting bony canal—the Fallopian aqueduct. The slightest hyperæmia or congestion of the nerve sheath or the lining of the canal is sufficient to cause paralysis of the facial muscles. This is easily brought about in some people by simple exposure to a draught of cold air on the side of the face.

It may also result from disease of the ear by extension of the process to the canal and the nerve itself.

If the case is of the simple kind and seen at once no change in the electrical reactions will be observed. It is not until some days have gone by that RD becomes developed. The mildest cases may not develop it at all,—in the most severe the reactions may be lost entirely, and between these two extremes every degree of severity is possible.

In applying current to the face it is as well to remember the skin of the face is thin and sensitive and the muscles are near the surface. Consequently strong currents of any kind are unnecessary and must not be used.

For treatment the indifferent electrode is placed on the back of the neck and the active electrode (kathode) over the nerve trunks and muscles labile. If RD is present the constant current is used, if not the induction coil is to be preferred.

Cases treated by electrical methods recover more rapidly that when it is neglected. In those due to ear or bone disease the prognosis is not so favourable. The case should be tested from time to time and the reactions carefully noted, as an indication of the progress of the case.

Paralysis of the **trapezius and sterno mastoid** muscles results from injury or disease of the spinal accessory nerve or its nucleus. When the sterno mastoid is paralysed the muscle does not stand out when the head is turned to the opposite side. Paralysis of one side of the trapezius is easily recognised by the drooping of the shoulder on the affected side. If it is atrophied as well as paralysed the outer half of the clavicle comes into view from behind when the patient places his hand on his head.

If the nerve has been divided electrical treatment is of no use until the ends have been joined together. Treatment must be carried out diligently so long as there are any signs of improvement. Constant current is to be employed—the indifferent electrode on the back of the neck and the kathode labile over the affected muscles.

Paralysis of the **Serratus magnus** is due to disease or injury of the positior thoracic nerve which arises from the fifth, sixth, and seventh cervical cords, owing to its exposed position in the neck, and the fact that it is unaccompanied by other nerve trunks, paralysis of the serratus alone is frequently found. The condition is easily recognised by directing the patient to extend his arms out straight in front. On examining the back the scapula is seen to be "winged"--instead of lying close to the thorax, the posterior border sticks out prominently. The function of the serratus is to hold the scapula close to the chest and pull it forward when the arm is raised above the horizontal. Should the deltoid be paralysed as well, the patient cannot raise the arm to the horizontal position. If the operator raises the arm and pushes it back, the patient resisting, the displacement of the posterior border of the scapula can be demonstrated.

The treatment presents no special features except that the indifferent electrode should be placed over the posterior triangle of the neck on the affected side.

Paralysis of the **deltoid** results from injury about or dislocation of the shoulder joint. It is supplied by the circumflex nerve which occupies an exposed position. It is the most common form of paralysis in the upper extremity and one of the most obstinate we have to deal with. There is flattening of the shoulder and on looking from behind the elbow is seen to come nearer the thorax on the affected side when the patient allows the arms to hang downwards. The patient is unable to raise the arm to the horizontal position, rendering the arm useless for many things, since there is no other muscle which can adequately take is place.

While recovery is the rule the prognosis should be guarded as a number of cases do not progress satisfactorily.

Musculo-Spiral Paralysis.—The muscles usually affected are the extensors of the wrist and fingers, and the supinator longus and brevis. If the injury is high up the triceps will be also involved.

The characteristic sign is wrist-drop. The most common cause is pressure, which may be produced in various ways, such as a crutch, axillary pad, falling asleep with the weight of the body resting on the arm, etc. It is most frequently associated with alcohol in the latter class of cases.

The prognosis bears a relation to the electrical reactions. If normal, recovery will be complete in about three weeks—while if RD is present, probably three months will be required. Electrical treatment undoubtedly hastens the process of recovery.

Ulnar Nerve.—Division of the nerve results in loss of power, wasting and RD in the hypothenar eminence, all the interossei, two ulnar lumbricales, adductor pollicis and inner head of the flexor brevis pollicis. Later on the proximal phalanges become over extended, and the distal phalanges are permanently flexed, due to the unopposed action of the long flexors and extensors. The hand becomes thin and flat, and the characteristic deformity known as the *claw hand* is produced. There is also loss of sensation in the little finger, ulnar half of the ring finger, and corresponding part of the palm.

Median Nerve.—This is sometimes divided at the same time as the ulnar. If injured alone there is paralysis, wasting and RD in the abductor, opponens, and outer head of the flexor brevis pollicis.

There is wasting of the thenar eminence, and the thumb is everted with the nail facing dorsally. Sensation is lost in thumb, index, middle and half of the ring finger and corresponding part of the palm.

The treatment is essentially the same as for other forms.

Cases of paralysis of a group of muscles which does not correspond to the distribution of any nerve trunk are not uncommon. In these the lesion will be found very often in the nerve root as it comes from the spine and before it reaches a plexus. This is known as "root paralysis." If the muscles supplied by the different nerve roots are known, the operator will easily manage to refer them to their proper origin. One of the most common of these is that known as Erb's paralysis. It results from disease or injury of the fifth and sixth cervical roots before they join the brachial plexus. The muscles affected are the deltoid, biceps, coraco-brachialis, brachialis-anticus and supinator longus.

It will be remembered that all these muscles are thrown into action in the normal subject by stimulation of Erb's point.

It will be also noticed that three nerve trunks are represented in the above group of muscles, viz., the circumflex supplying the deltoid, the musculo-cutaneous supplying the coraco-brachialis, brachialis-anticus and biceps, and the musculo-spiral supplying the supinator longus. The position of the arm and hand in this condition is very characteristic. The arm hangs straight down by the side, and the hand is rotated inwards so that the palm is looking backwards. It has been humourously referred to as the "policeman's tip" position, which is a fairly accurate description of it. It has also been called "obstetrical" palsy, as it has often resulted from traction on the arm in difficult labour.

The prognosis in any case depends on the nature and severity of the lesion producing it. If due to pressure and involvment by malignant disease it would, of course, be very unfavourable. If due to injury at birth the extent of the injury will determine the nature of the prognosis. In severe cases where the nerves are lacerated or torn out from the cord recovery is practically impossible. Most cases fortunately are less severe than this, and recovery to a greater or less extent is the rule. In the electrical department of the London Hospital six cases have been treated during the last eighteen months—two are still under treatment—all have done or are doing well. It is not to be supposed that such a clean record will continue. The lesion, in none of them, has been unduly severe, but there is no doubt recovery has been assisted and hastened by electrical treatment. Treatment must be carried out regularly and persistently so long as improvement continues. The constant current is to be preferred. The anode to the back of the neck, and the cathode labile over the affected muscles.

It is important to remember that great care is to be taken in dealing with children, so as not to frighten them by using too strong a current at the beginning. Indeed it is a good rule at the first application not to turn on any current at all, but to have everything else arranged as usual. This gains the child's confidence, and at the next application a very mild current is used. This is gradually increased on subsequent occasions until a sufficiently strong current is reached.

Peripheral paralyses of the lower limb not due to a lesion of the brain or spinal cord are very uncommon. The groups will be referred to their nerve trunks or nerve roots. The treatment is the same as for other forms.

Neuralgia.—The electrical treatment of neuralgia follows one or other of two main principles ; that of counter-irritation or the production of a state of anelectrotonus in the painful area. The choice of the two methods depends on the nature of the painful affection. If it is a referred pain counter-irritation is indicated, applying with a wire brush, the current from a secondary coil having a long fine wire winding. The surface of the skin must be quite dry. If the pain is due to a local neuritis this method would probably make it worse. The constant current is to be used in such a case, the anode being placed stabile over the painful area and a large current passed.

In all cases the cause of the pain must be carefully sought for, as the indiscriminate use of one or other method is sure to be highly unsatisfactory.

Facial Neuralgia.—This is one of the most common kinds to be met with and in its severe form—known as tic douloureux—gives rise to the greatest suffering.

In dealing with this disease half measures are useless or worse. An electrode of sheet lead, tin, or pewter should be cut roughly to the shape of the letter E. The upright part is applied along the side of the face and the three horizontal parts are placed along the forehead, cheek and chin respectively. Several thicknesses of lint are to be cut to the same shape, well moistened and placed between the metal plate and the skin. The patient reclines on a couch and the metal plate is made the anode. The indifferent electrode should be a large mass of potter's clay, powdered carbon electrode or any large conducting surface that can be accurately fitted to the surface of the body. The current is to be turned on very gradually until about fifty milleamperes are passing, and allowed to continue for from twenty to thirty minutes. This should be repeated daily until the tendency to the paroxysms disappears. The current on each occasion must be turned off very gradually or severe shocks will result which might have serious results.

It is an advantage sometimes to saturate the lint with a one per cent solution of hydrochlorate of quinine. The latter is thus introduced by cataphoresis and has answered in cases where everything else had failed. Cocaine may be used and in some cases the effect is immediate, but not of a permanent character.

Another common form of neuralgia is Sciatica. As in other forms it is important to ascertain the cause. If due to disease of the prostate, hemorrhoids, anal fissure, &c., it comes under the head of a referred pain and counter irritation with the faradic brush or high frequency effluve is indicated.

If due to local neuritis or perineuritis, rest, warmth and the constant current constitute the best method of treatment.

Electricity may be applied by means of large electrodes—one against the iliac fossa and the other along the course of the nerve, using a current of from thirty to fifty milleamperes, for from ten to twenty minutes. This large current is required on account of the deep position of the nerve. Or the patient may sit in the ordinary full bath with just enough water to cover the legs. A current of about 200 milleamperes is required. As recovery takes place the sinusoidal current may be substituted with advantage. It must not be used until the patient can bear it comfortably.

Sciatica due to thickening or adhesions of the nerve sheath are most tedious and not likely to be much benefitted by electrical treatment alone.

Nerve Deafness.—Impaired hearing, due to affection of the auditory nerve is sometimes benefitted by the constant current. A bifurcated electrode is used connected to the negative pole and applied to the ears.

The current is to be continually varied in strength ; this is best done by a rythmic interrupter. It should not reach higher than ten milleamperes at any time, and applied for about five minutes. The patient must be carefully watched and the current reduced on the sign of faintness.

Tinnitus aurium often responds to electrical treatment very satisfactorily. The bifurcated electrode is used and made the anode, which tends to reduce the noise, while the kathode increases it. The current must be turned on and off very gradually or the noises may return worse than before.

The brush discharge from the static machine and the high frequency effluve applied locally, have been recommended.

Wasting and Weakness of Muscles.—This frequently follows on joint affections and is brought about by disuse. Simple treatment with the induction coil is all that is required in most cases.

Myasthenia Gravis.—So far as is at present known electricity is not of mnch use in this condition. Its chief interest from the point of view of the medical electrician is on account of the peculiar reaction found in the muscles of a patient suffering from this disease. When testing a muscle with the coil current the amount of response rapidly decreases, and the muscle may completely relax though the current continues to flow. This takes place in the space of a few seconds in some cases. At the same time the muscle will react normally to the single closure of the constant current. The disease is very uncommon.

Myalgia.—By this is meant muscular pain—the result of over-fatigue—a condition which is brought about very easily in debilitated persons. It is most frequent in the trunk muscles and is accompanied by local tenderness and increase of the pain on movement. It is found at the origin or insertion of certain muscles the most common of which are the trapezius, spinal muscles, pectoralis major and minor, (infra-mammary pain) and rectus abdominis.

The constant current up to 20 milleamperes with the anode over the painful areas should be tried—or better, the constant current full bath if practicable. Later on as the pain and tenderness subsides the induction coil or sinusoidal current will be found most useful.

Localised Inflamations.—In general, electricity should not be used during the acute stage of inflamation—but in the later stages when there is a state of passive congestion and the presence of inflamatory products, electricity is capable of dealing with the condition in a very satisfactory manner. That it is not more used in this connection is to be deplored since its power to hasten recovery is beyond doubt. The constant current is to be used and the amount of current large, with large electrodes. There does not seem to be any special advantage attached to either pole except in painful spots when the anode would have the more soothing effect.

The application above referred to is very useful in painful affections of joints whether the result of injury or disease. It has been successfully applied in a case of injury, almost immediately after the accident, with most excellent results. There was great swelling present and also tenderness and discolouration. Recovery was rapid and complete, due no doubt to the great stimulus, to the local circulation by which the effusion was carried away rapidly.

Chronic joint pains of rheumatic or gouty origin are also greatly benefitted by electrical applications. The monopolar bath or some modification of it, is the best method of applying it. The water should be as warm as can be borne comfortably.

In these cases treatment must be carried out thoroughly and systematically, but the results will repay the trouble involved.

Rheumatoid Arthritis.—Electricity is used empirically in this disease—as indeed are all other remedial agents. A number of cases do well, others again do not improve at all. The sinusoidal full bath is the best method and should be always tried in obstinate cases. It is not improbable that the local introduction of medicaments by cataphoresis may come to be an important method of dealing with this most troublesome affection.

Lately the high frequency current, either in the form of a brush discharge or passed through the joint by ordinary electrodes, has been advocated; the results have been satisfactory and the method is worthy of further investigation.

Circulatory Disturbances.—It has already been mentioned that general electrization has an influence on the blood-pressure and that this influence was not the same in all the methods employed. Static charging tends to raise blood-pressure while high frequency tends to lower it. This is important and explains why in some cases the method employed was either useless or made the patient worse. In a case af neurasthenia for instance, if the blood-pressure is high, high frequency should be used, and if low the static machine will be found most effectual.

Cardiac Failure.—In cases of impending death, electrical stimulation of the heart itself should not be attempted as it is just as likely to cause the very thing we wish to prevent—that is stoppage of the heart's action. It is best to use an induction coil a with long fine secondary wire, and metallic brush electrode to stimulate the surface of the body. This sets up a great reflex effect and is a stimulus to respiration and the heart's action. The nose and upper lip are good points to influence respiration. If desired the phrenic nerves in the neck may be directly stimulated and so set up contractions of the diaphragm. Two electrodes each about one inch in diameter are to be used, and one of them is mounted on a handle with a closing key. They are applied under the posterior border of the sterno-mastoid muscles, and the circuit closed and opened at intervals of about two seconds. This has been successfully employed in chloroform poisoning.

Raynaud's Disease—Chillblains.—The use of electricity in these conditions was referred to when dealing with the electric bath. Of the value of the method the author can testify from experience with patients and his own case. He suffered the greatest discomfort from chillblains every winter until he tried the electric bath. A very short course of treatment removed the trouble completely some years ago and there has been no return. The coil or sinusoidal current will answer very well in most cases —using a foot-bath of any non-metallic material with an electrode at each end. The hands or feet are immersed, and the patient can regulate the current by gradually approaching the electrodes until it is sufficiently strong yet not uncomfortable or painful.

In the most severe cases and also in Raynaud's disease the constant current answers best. If confined to one limb, its extremity should be immersed in the water which is connected to one pole of the battery and an electrode connected to the other pole is placed on the limb higher up. The current is to be fairly strong and may be made and broken at frequent intervals so as to set up contractions in the limb. If there are any cracks in the skin they should be first covered over with rubber adhesive plaster during the bath.

Disorders of Digestion.—Electricity is often useful in disorders of the digestive tract. Dyspepsia associated with neurasthenia, gastralgia and gastric myasthenia are all amenable to electrical treatment. A slow sinusoidal current is most useful, one electrode being placed on the lower dorsal spine and the other over the epigastrium. It should be applied daily or at least three times a week for ten minutes. Dilatation of the stomach has also been successfully treated by this means.

Constipation.—When this is due to atony of the muscular coats of the intestine, electricity is probably the most efficient method of treatment known. Large currents and large electrodes are to be used. If constant current is to be employed the anode is the indifferent electrode placed under the lumbar spine as the patient reclines. The kathode or active electrode is a disc about four inches in diameter and applied with firm pressure over the front abdominal wall working it round rather slowly from the cæcum along the course of the colon to the sigmoid flexure where it is allowed to rest for from two to five minutes, when the process is repeated.

This should be done every other day for three or four weeks. Instead of the constant current a rythmic interrupter may be placed in circuit, or better still, use a sinusoidal current of low frequency—from two to four periods per second. Either of these currents is a more energetic stimulant to unstriped muscle than the constant current. The usual result of such treatment is for the bowels to become more regular of their own accord and to remain so after the treatment is discontinued. This is not the invariable result, however, and under no circumstances must a cure be promised in this—or any other –affection.

In obstinate cases one pole is connected to a rectal douche electrode.

Fig. 69. Rectal Douche Electrode.

This is first inserted and then a small quantity of water or normal saline solution is pumped in. The liquid becomes the electrode and so protects the mucous membrane from injury by electrolysis. The indifferent electrode is placed on the lumbar spine or epigastrium and a rythmically interrupted or slow sinusoidal current used for about ten minutes. It sometimes happens that the bowel is provoked to action before this time elapses.

Anal Fissure and haemorrhoids in the early stage, are now successfully treated with high frequency currents. The method is to use a vacuum or other glass electrode of special shape and large enough to distend the anus. It is connected to the top of the resonator and the current turned on for two or three minutes daily, the patient lying on the condensor couch. The method is not satisfactory in the case of piles that have existed for a long time and become chronic.

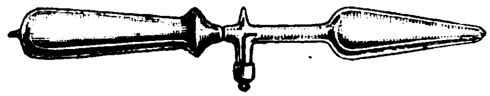


Fig. 70 High Frequency Rectal Electrode.

Incontinence of Urine.—Lewis Jones in dealing with this subject divides the cases into three main classes. In the first there is want of tone in the sphincter of the bladder and urine is expelled involuntarily during any muscular effort which involves the action of the abdominal muscles. The second occurs in women with irritibility of the bladder, and this discharges its contents with pain and spasm at frequent intervals.

In the third form the muscular apparatus is normal, but the bladder empties itself spontaneously during sleep.

In the first class a good deal can be done by electrical treatment to relieve this troublesome and annoying condition. A bare metal sound is introduced into the urethra as far as, but not into, the bladder, as one electrode, and the indifferent electrode is placed over the lumbar region. A mild current from the induction coil is turned on for about ten minutes. In males a perineal electrode is usually all that is required, the sound being reserved for the worst cases. The perineal electrode is of an acorn shape, and so arranged that a fresh cover can be easily and quickly put on for each application.

For the second class of cases electricity so far has not been of any help.

The third class or true nocturnal incontinence is due to the persistance of the infantile mechanism of micturition. When awake the patient is the same as other normal subjects but when asleep the inbibitory centre is so much in abeyance that it cannot maintain its action over the bladder sphincter.

The method just described is suitable but the current used must be strong enough to produce painful impressions if it is to be of any use. If the constant current is used it must be frequently reversed to prevent injury to the parts in contact with the electrodes.

In treating girls about the age of puberty it is essential to avoid any manipulation of the parts. The treatment can be carried out in an electric bath,—an electrode is placed between the thighs but outside the bathing dress; this is in place of the foot plate ordinarily used.

Functional Disorders of the Male Sexual Organs.—Electricity has been much used in sexual disorders, but it has not proved itself of great value.

Most sexual disability is due either to nervousness or over indulgence, and it is not easy to see how electricity locally applied could, under such circumstances, have any great value. Erb, however, has advised the use of the constant current, from five to ten milleamperes. A small button-shaped electrode, positive, to the perinaeum, and the other larger electrode to be moved up and down slowly over the lower dorsal and lumbar spine.

Orchitis and Epididymitis have been successfully treated with the constant current with the electrodes placed on the front and back of the scrotum. In the acute stage but very mild currents can be borne—one half to one milleampere. In the chronic stage ten or twenty milleamperes may be employed.

Diseases of Women.—Electricity is so much used in gynæcology that a work on that subject should be consulted for full information on that branch of electrotherapeutics. Only a few of the most common conditions can be referred to here.

Pruritus Vulvae is sometimes very successfully treated by the high frequency effluve and the condensor electrode on the same principle as in dealing with anal fissure.

Amenorrhœa.—The effect of general electrization on the menstrual function has been known and made use of for many years. Local treatment as a rule is not necessary. The electric bath may be used but static charge and discharge seems to be the most efficient method. In extreme cases, where the general health is fairly good, local stimulation with the faradic current may be employed. Special electrodes are necessary for this purpose.

Dysmenorrhœa.—The static machine is also most useful in this condition. Positive charging with the negative breeze to the loins and spine should be applied daily for ten minutes for a week before the next period is expected.

Where there is ovarian pain and tenderness, the constant current may be employed with better results. Large electrodes placed on lower lumbar and hypogastric regions are to be used. A current of from forty to fifty milleamperes is passed for from twenty to thirty minutes.

Extra Uterine Pregnancy.—If employed before the end of the third month, galvanism or faradism is very successful in causing the death of the foetus. An electrode with a bulbous end and insulated shank is passed into the vagina or rectum so as to get it as near as possible to the sac. A large indifferent electrode is placed externally also as near as possible to the sac. Currents of twenty to thirty milleamperes are passed for a few minutes daily until it is found the mass has ceased to increase in size. The current should be frequently reversed to counteract injury to the mucous membrane by electrolysis.

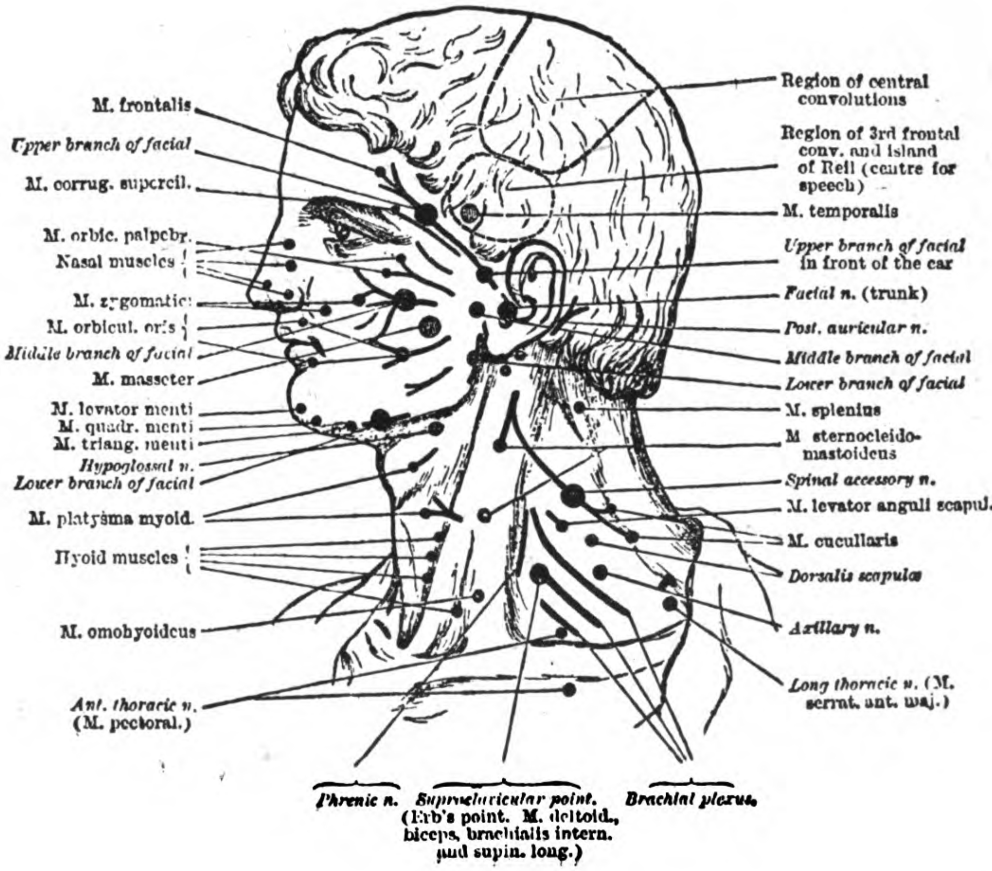
Diseases of the Skin.—The advent of the high frequency effluve has caused considerable attention during recent years to be given to the use of electricity in the treatment of cutaneous disorders. The disappearance of old standing acne in patients undergoing a course of electric baths is a matter of common observation.

The static brush is also used with success in eczema, psoriasis, pruritus, alopteca areata, lupus vulgaris, lupus erythematosus, and impetigo. And in all these the effluve from the high frequency machine is equally applicable and its effect may be even better in some cases. The latter in the author's hands has been most useful in psoriasis, eczema and alopecia areata. How far it may prove to be of value in premature baldness in otherwise healthy individuals is not yet determined.

Electricity as a test of Death.—In the opinion of Dr. Lewis Jones, the electrical reactions of muscle afford a complete test of death, as the contractibility of the muscles only persists for a short time after death and then disappears entirely. No person should be buried so long as the muscles contract when stimulated by the induction coil current.

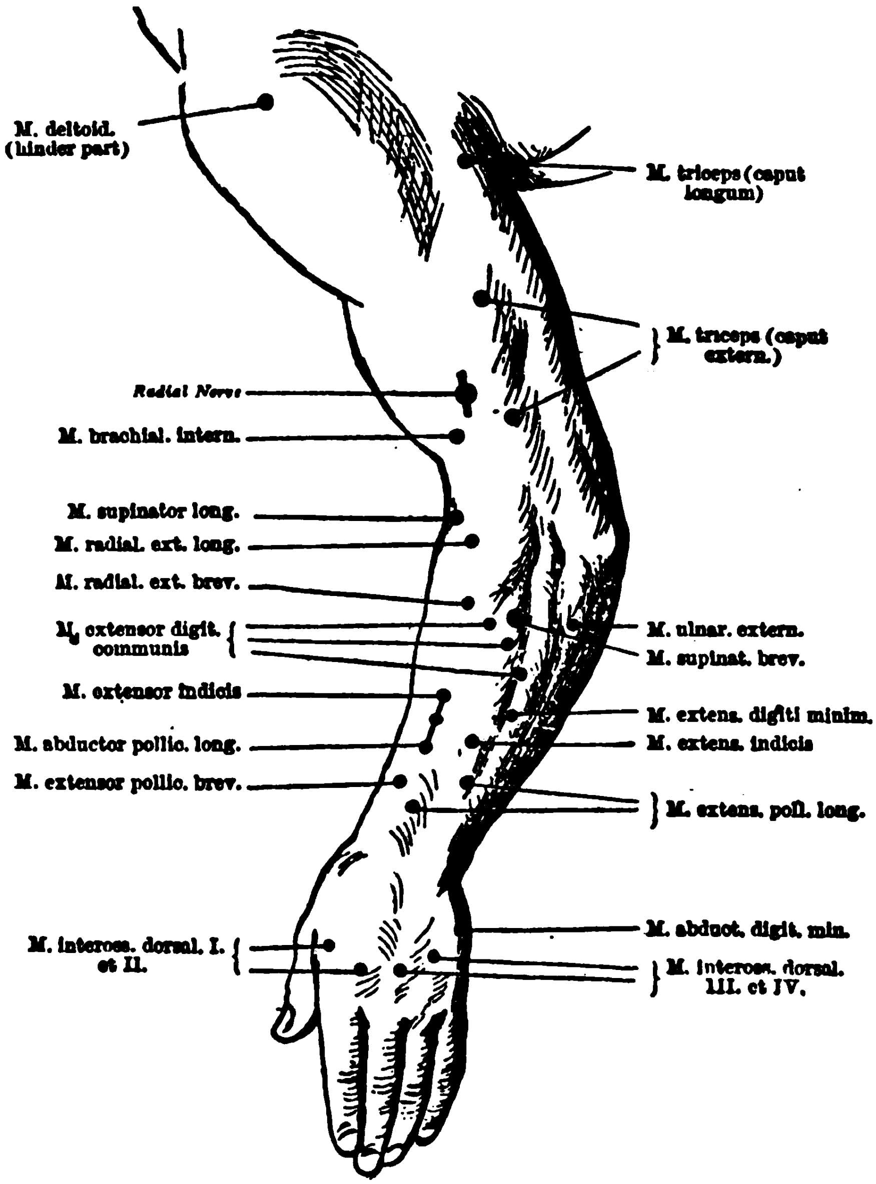
In his opinion the morbid fears of the public on the subject of the burial of persons not really dead could be completely allayed if this test were always applied before the certificate of death were signed.

PLATE I.



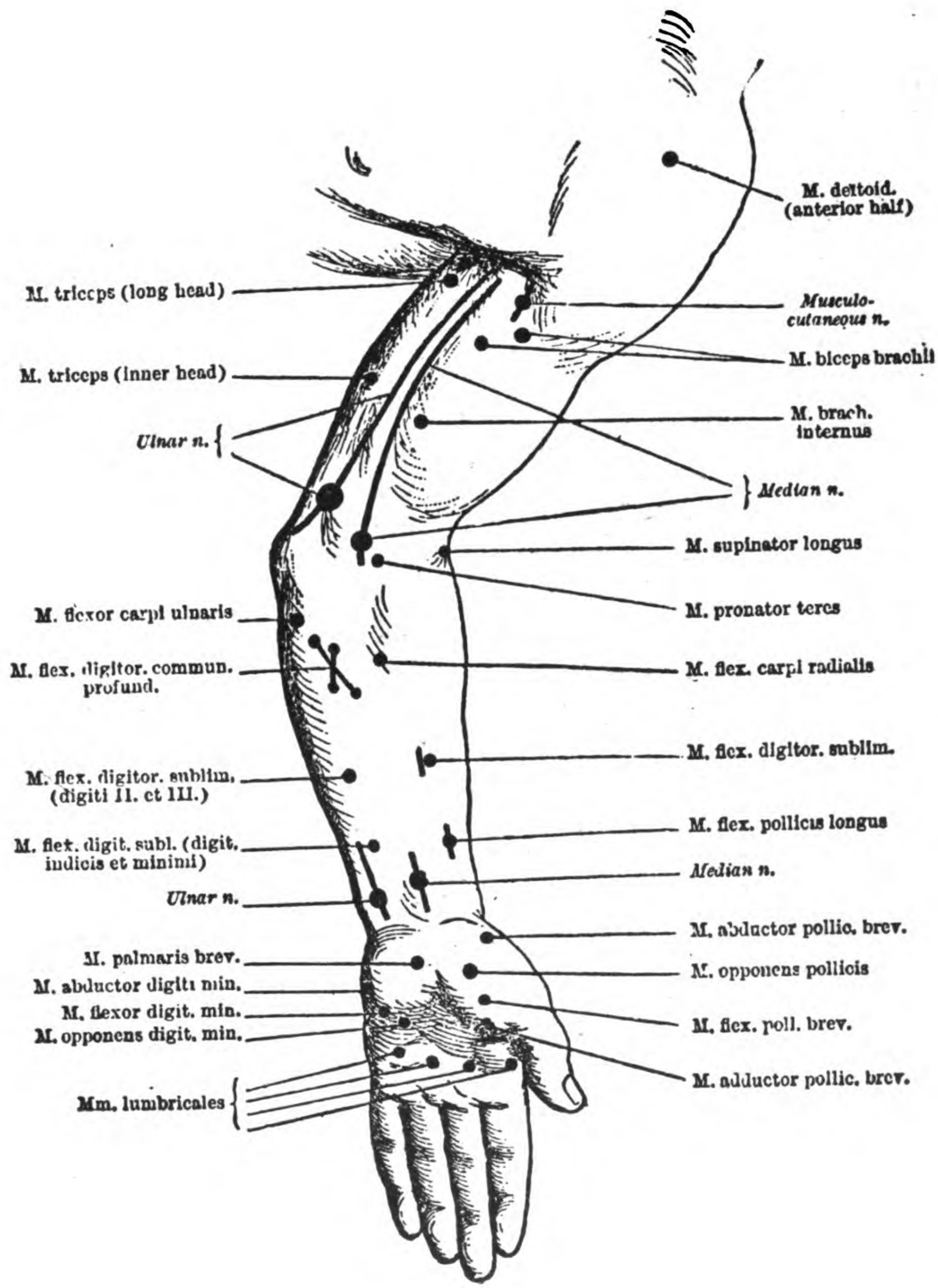
M. frontalis
Upper branch of facial
M. corrug. supercil.
M. orbic. palpebr.
Nasal muscles
M. zygomatic.
M. orbicul. oris
Middle branch of facial
M. masseter
M. levator menti
M. quadr. menti
M. triang. menti
Hypoglossal n.
Lower branch of facial
M. platysma myoid.
Hyoid muscles
M. omohyoideus
Ant. thoracic n.
(M. pectoral.)
Region of central convolutions
Region of 3rd frontal conv. and island of Reil (centre for speech)
M. temporalis
Upper branch of facial in front of the ear
Facial n. (trunk)
Post. auricular n.
Middle branch of facial
Lower branch of facial
M. splenius
M. sternocleido-mastoideus
Spinal accessory n.
M. levator anguli scapul.
M. cucullaris
Dorsalis scapulae
Axillary n.
Long thoracic n. (M. serrat. ant. maj.)
Phrenic n.
Supraclavicular point.
(Erb's point. M. deltoid., biceps, brachialis intern. and supin. long.)
Brachial plexus.

PLATE II.



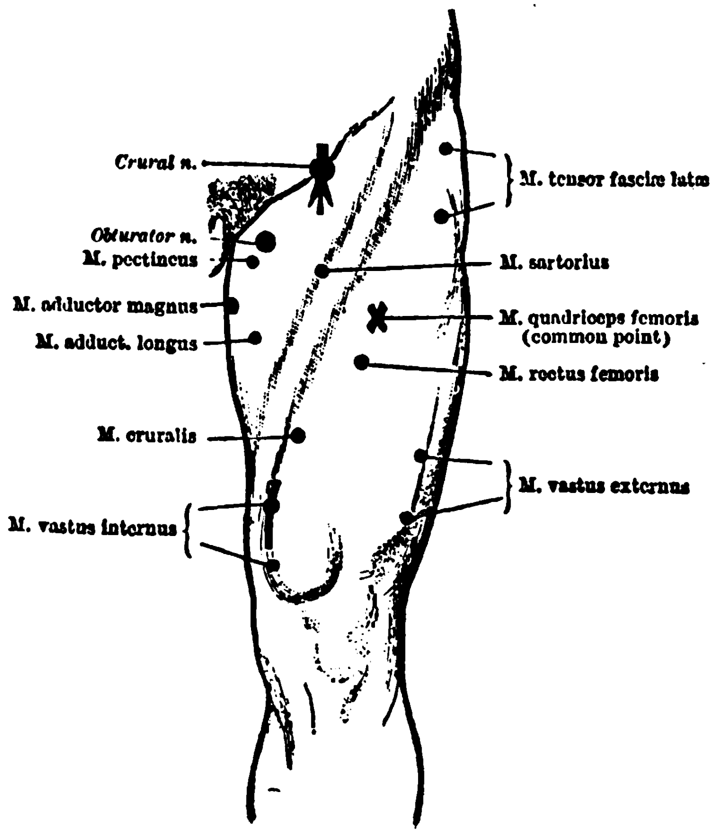
M. deltoid.
(hinder part)
M. triceps (caput longum)
M. triceps (caput extern.)
Radial Nerve
M. brachial. intern.
M. supinator long.
M. radial. ext. long.
M. radial. ext. brev.
M. extensor digit. communis
M. ulnar. extern.
M. supinat. brev.
M. extensor indicis
M. extens. digiti minim.
M. abductor pollic. long.
M. extens. indicis
M. extensor pollic. brev.
M. extens. poll. long.
M. abduct. digit. min.
M. inteross. dorsal. I. et II.
M. inteross. dorsal. III. et IV.

PLATE III.



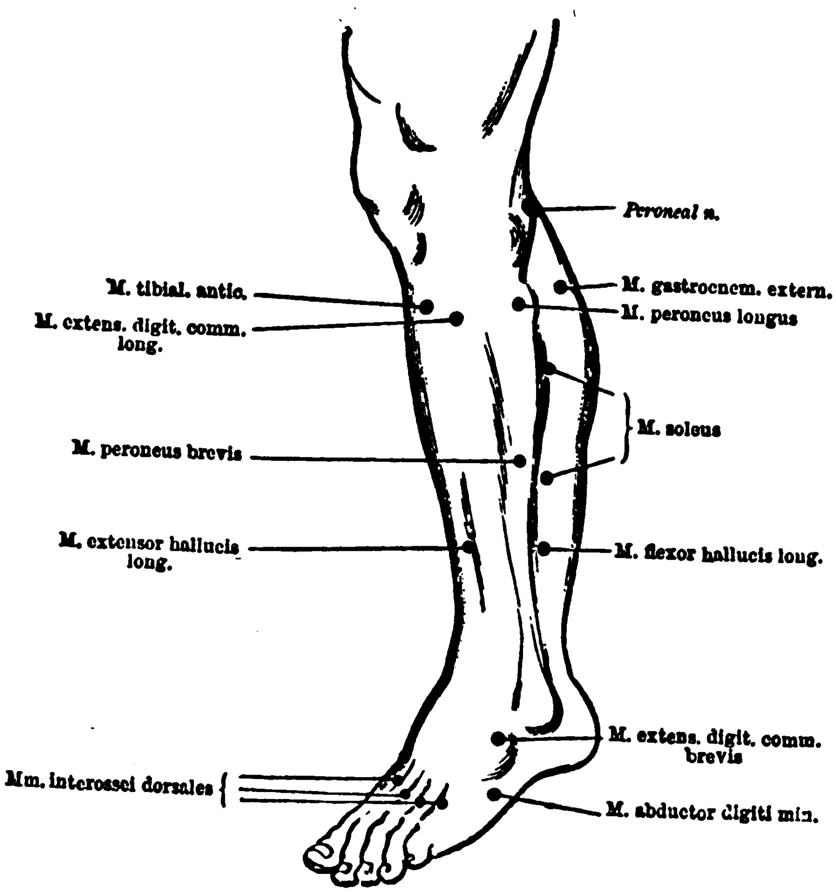
M. deltoid. (anterior half)
M. triceps (long head)
Musculo-cutaneous n.
M. biceps brachii
M. triceps (inner head)
M. brach. internus
Ulnar n.
Median n.
M. supinator longus
M. pronator teres
M. flexor carpi ulnaris
M. flex. digitor. commun. profund.
M. flex. carpi radialis
M. flex. digitor. sublim.
M. flex. digitor. sublim. (digiti II. et III.)
M. flex. pollicis longus
M. flex. digit. subl. (digit. indicis et minimi)
Median n.
Ulnar n.
M. abductor pollic. brev.
M. palmaris brev.
M. opponens pollicis
M. abductor digiti min.
M. flexor digit. min.
M. flex. poll. brev.
M. opponens digit. min.
M. adductor pollic. brev.
Mm. lumbricales

PLATE IV.



Crural n.
Obturator n.
M. pectineus
M. adductor magnus
M. adduct. longus
M. cruralis
M. vastus internus
M. tensor fasciæ latæ
M. sartorius
M. quadriceps femoris (common point)
M. rectus femoris
M. vastus externus

PLATE V.



Peroneal n.
M. tibial. antic.
M. gastrocnem. extern.
M. extens. digit. comm. long.
M. peroneus longus
M. soleus
M. peroneus brevis
M. extensor hallucis long.
M. flexor hallucis long.
M. extens. digit. comm. brevis
Mm. interossei dorsales
M. abductor digiti min.

PLATE VI.

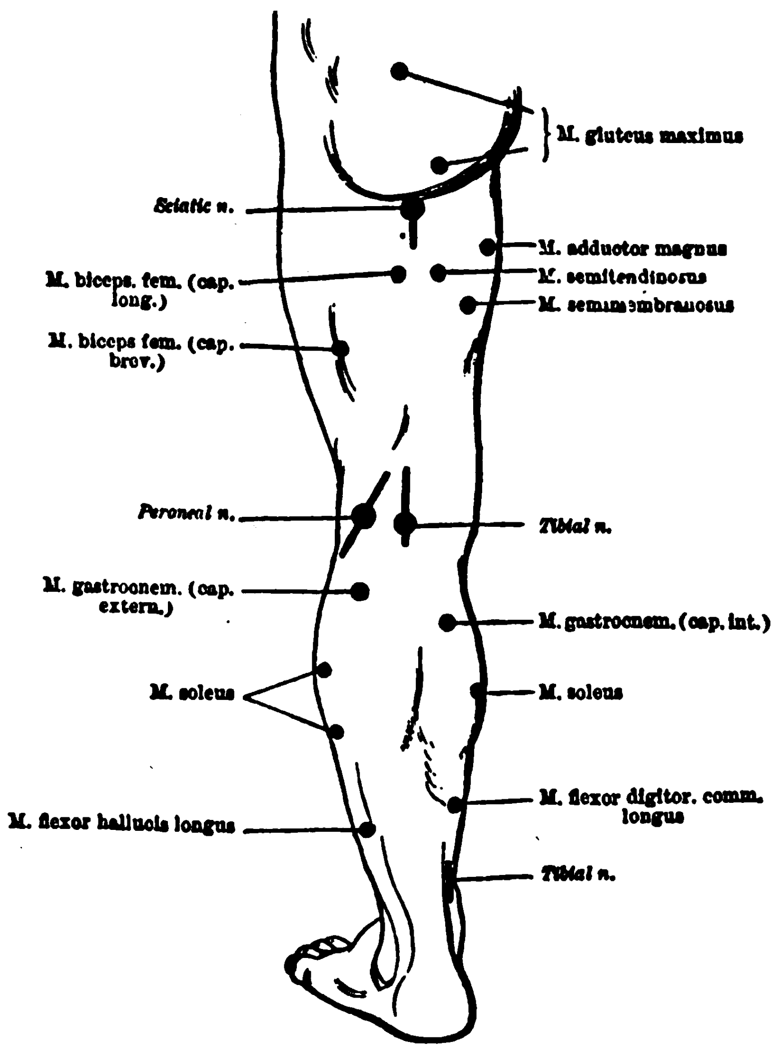

M. gluteus maximus
Sciatic n.
M. adductor magnus
M. biceps. fem. (cap. long.)
M. semitendinosus
M. semimembranosus
M. biceps fem. (cap. brev.)
Peroneal n.
Tibial n.
M. gastrocnem. (cap. extern.)
M. gastrocnem. (cap. int.)
M. soleus
M. soleus
M. flexor digitor. comm. longus
M. flexor hallucis longus
Tibial n.

PLATE VII.

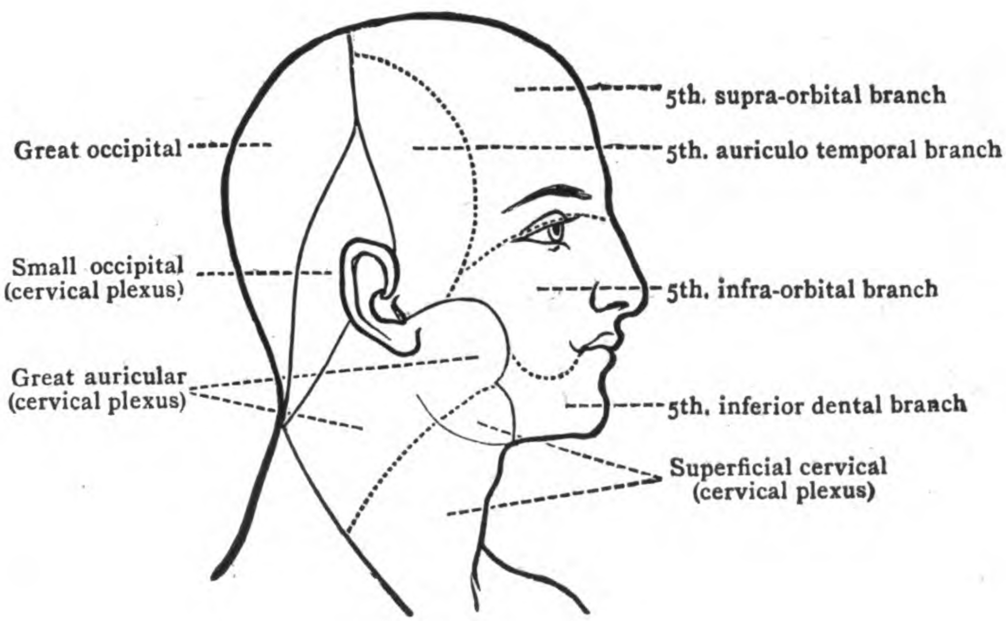

5th. supra-orbital branch
Great occipital
5th. auriculo temporal branch
Small occipital
(cervical plexus)
5th. infra-orbital branch
Great auricular
(cervical plexus)
5th. inferior dental branch
Superficial cervical
(cervical plexus)

PLATE VIII.

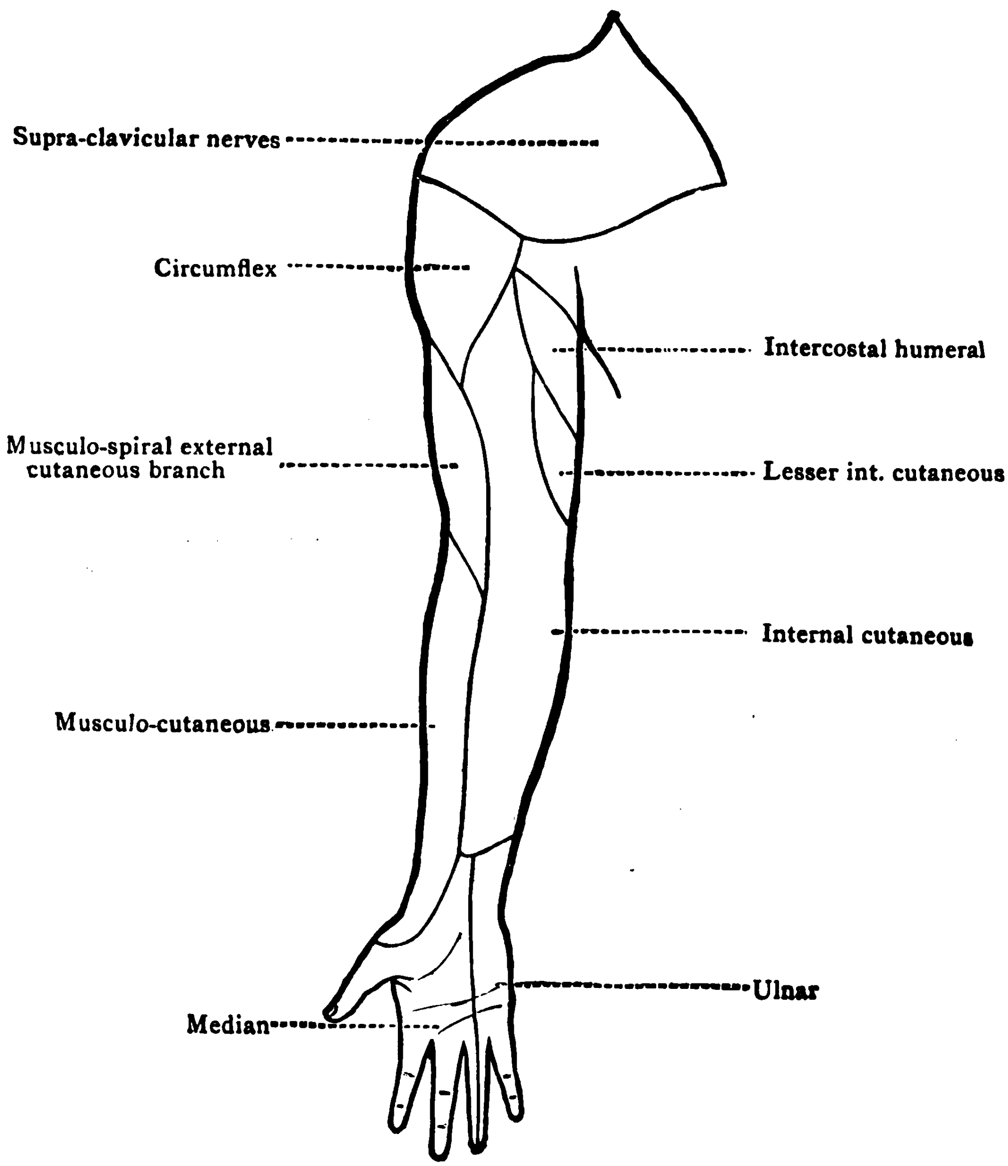
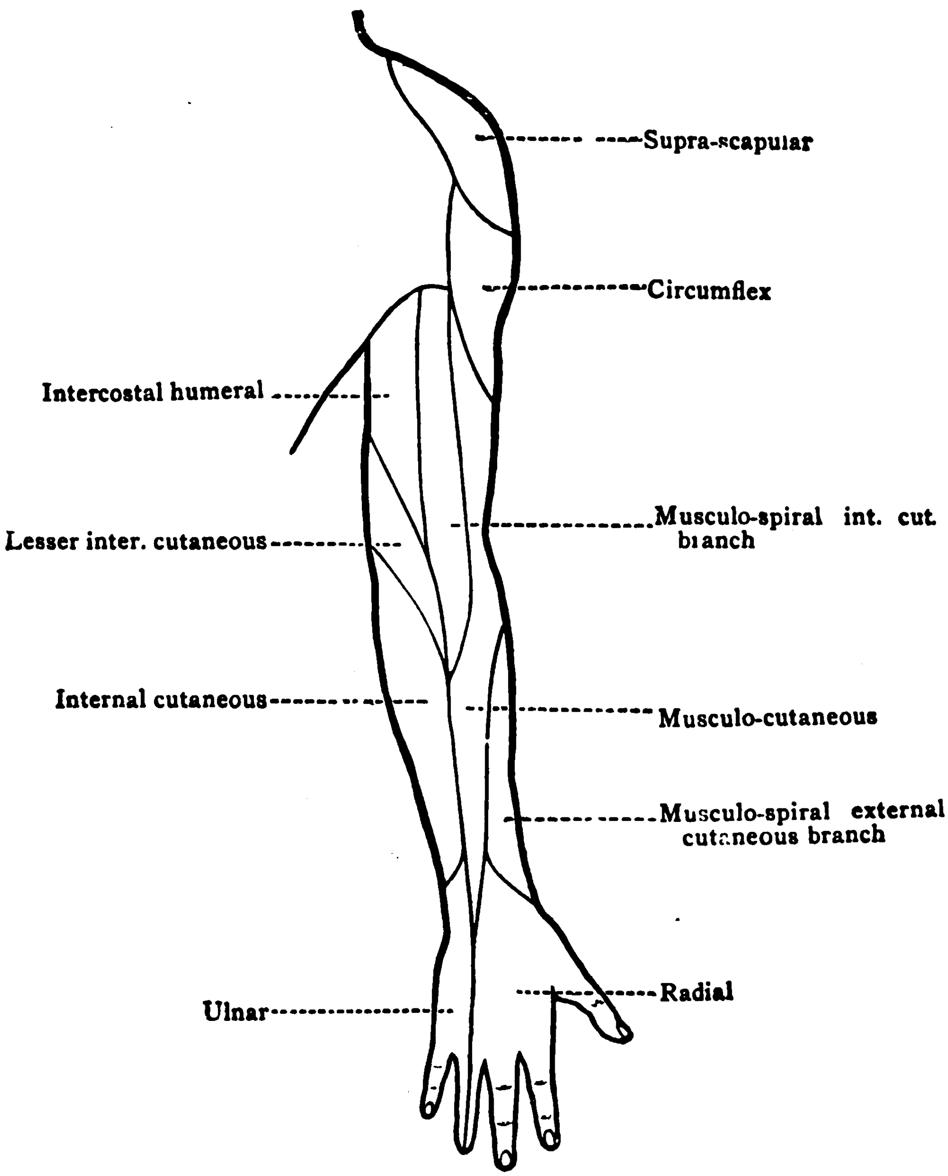
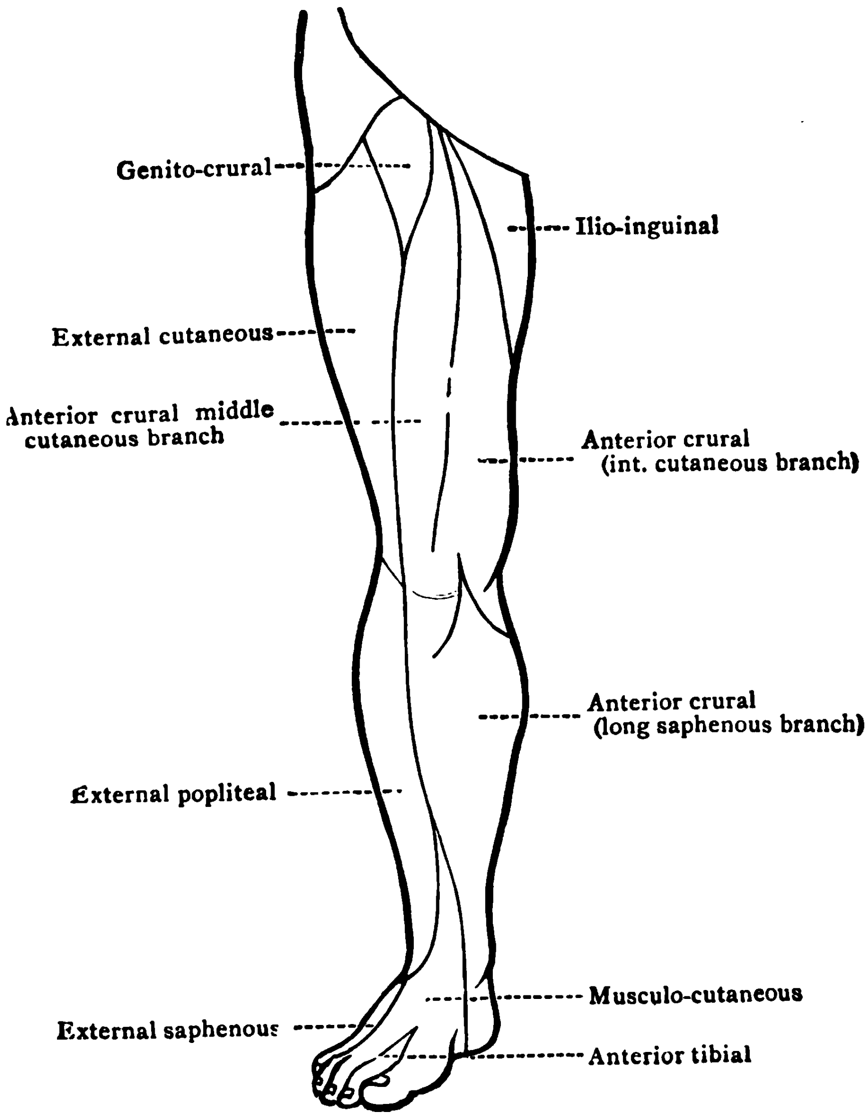

Supra-clavicular nerves
Circumflex
Musculo-spiral external cutaneous branch
Musculo-cutaneous
Median
Intercostal humeral
Lesser int. cutaneous
Internal cutaneous
Ulnar

PLATE IX.



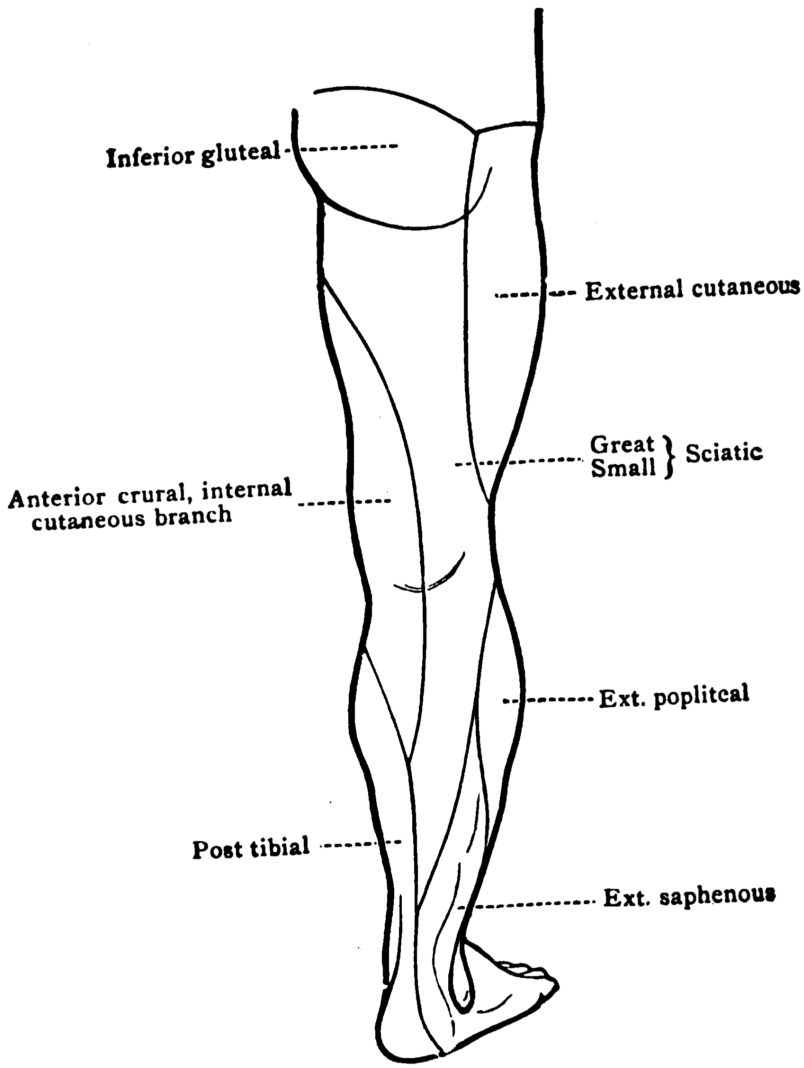
Supra-scapular
Circumflex
Intercostal humeral
Musculo-spiral int. cut. branch
Lesser inter. cutaneous
Internal cutaneous
Musculo-cutaneous
Musculo-spiral external cutaneous branch
Radial
Ulnar

PLATE X.



Genito-crural
Ilio-inguinal
External cutaneous
Anterior crural middle cutaneous branch
Anterior crural (int. cutaneous branch)
Anterior crural (long saphenous branch)
External popliteal
Musculo-cutaneous
External saphenous
Anterior tibial

PLATE XI.



Inferior gluteal
External cutaneous
Great
Small
Sciatic
Anterior crural, internal cutaneous branch
Ext. popliteal
Post tibial
Ext. saphenous

INDEX.

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