The Nursing Record Series

OF

MANUALS & TEXT BOOKS.

No. 3.

A MANUAL OF

PRACTICAL ELECTRO-THERAPEUTICS.

By ARTHUR HARRIES, M.D.,

AND

H. NEWMAN LAWRENCE, M.I.E.E.

WITH PHOTOGRAPHS AND DIAGRAMS.

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A MANUAL OF

Practical Electro-Therapeutics.

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EDITOR.

A MANUAL OF

PRACTICAL ELECTRO-THERAPEUTICS.

(ILLUSTRATED.)

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THERAPEUTICS, AND IN GRATEFUL ACKNOWLEDGMENT OF

HIS MANY ACTS OF PERSONAL KINDNESS,

THIS BOOK IS DEDICATED BY

THE AUTHORS.

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PRACTICAL LESSONS IN ELECTRO-THERAPEUTICS.

AUTHORS' PREFACE.

THAT portion of the function of electricity dealt with in these lessons is one which has, unfortunately, lent itself but too easily to the purposes of the charlatan in his impositions upon a credulous public.

One of the objects, therefore, of the course of lectures upon which these lessons are based was to bring forward, in an easily assimilable form, first, the elementary facts of the science; second, the physiological and pathological phenomena, which depend for their production upon the application of various forms of electricity; and last, the methods by which it has hitherto been possible to employ this agent in the treatment of pathological conditions.

It was thus intended to keep clear of purely theoretical statements, and to illustrate by experiments such points as had important bearing upon the elucidation of the subject.

In these lessons we have adhered to the same plan, replacing actual experiment by diagrams with descriptive letterpress, and avoiding, as far as may be consistent with clearness, the use of technical terminology.

To meet the requirements of Nurses and students, in showing how electricity may be used in the treatment of disease, we have arranged our material in such a way as to lead gradually from the consideration of the groundwork upon which the science has been constructed, *always bearing in mind its Medical aspect*, to that of the delicate processes by which dosage can be accurately measured, and either localized or widely diffused as the nature of the case may demand.

It is needless to remind our readers that these lessons are not meant to be inclusive in any sense of the term. Rather are they intended to form an introduction to the study of more comprehensive works, and to point the way in which a student may most advantageously proceed to gain a thorough knowledge of the subjects treated.

THE AUTHORS.

LESSON I.

Energy—Electrical Energy—Transformation of Energy—Re-transformation —Loss — Electric Generators : Mechanical, Chemical, Thermal— Similarity of Electric Currents—Comparison of Generators.

WHAT is electricity? The question is very difficult —we might almost say impossible—to answer at the present time, with any degree of certainty. There are many theories, but it would be useless to attempt to discuss them here. In evidence of the difficulty of giving a satisfactory definition of electricity, we may refer our readers to the words of one of the greatest physicists of the day (Sir William Thomson), who, in his inaugural address delivered last January to the Institution of Electrical Engineers, said that he had spent forty-two years in endeavouring to fathom the problem of what electricity is—forty-two years in which he might almost say the subject was never entirely absent from his mind—and yet he was still unable to give any solution of the problem. We will not theorise on the subject, but consider it sufficient for the purposes of these lessons if we regard electricity as a form of energy.

ENERGY.

Energy in some form is present throughout all nature. We cannot alter its total quantity. We can neither create nor destroy it, but we can change or transform its character, and so cause it to perform useful work. In the course of these changes various phenomena may be observed, to some of which it will be our duty to call special attention.

Most, if not all, of the known forms of energy may be transformed into electrical energy. The forms of energy best suited for illustration are three in number—*viz.* (*a*) mechanical energy, (*b*) chemical energy, and (*c*) thermal energy. All energy of either of these three forms may be potential or kinetic—potential when at rest, kinetic when in action. We will briefly call attention to some well-known illustrations of these forms of energy before proceeding to to consider how they may be transformed into electrical energy.

MECHANICAL ENERGY.

(*a*) Mechanical energy. Every machine which possesses a handle and has to be driven involves the use of mechanical energy. If we take a sewing machine with a handle or treadle, and we turn that handle or treadle, we employ mechanical energy; the energy in the arm or leg of the operator is potential so long as the limb is at rest, but it becomes kinetic so soon as we exert the limb to set the machine in motion. In winding up a clock we employ mechanical energy, and store it in potential form in the raised weights or coiled spring, and it is given out again in kinetic form as the machine performs its work.

CHEMICAL ENERGY.

(*b*) For illustration of chemical energy we need only point to an ordinary gas-burner. Here we have the potential energy latent in the gas as it comes from the main, and in the oxygen of the air, becoming transformed by combustion, into the kinetic energy manifested in the heat and light of the gas flame.

THERMAL ENERGY.

(*c*) As regards thermal energy, we may refer to the steam-engine, where the potential energy of combustion is transformed into the kinetic energy of steam.

TRANSFORMATION.

We may now consider more particularly the methods of transforming each of the above-named forms of energy into electrical energy. First, then (*a*) of *Mechanical Energy*. The simplest form of mechanical energy capable of being transformed into electrical energy is friction. If we take a rod of ebonite or sealing-wax, and rub it lightly on dry fur or silk, or even upon the coat sleeve, we shall find that some of the energy of the rubbing has been transformed into electrical energy; for, on presenting the freshly rubbed rod to some small cuttings of thin paper, we shall find that they are attracted to the rod, and jump through a perceptible air space to adhere to it, thus proving the presence of electricity. A better illustration is found in the old-fashioned electrical machine, where a disc or a cylinder of glass is made to revolve rapidly while a pad or pads rub against its surface. By means of this arrangement the utility of friction is much increased, and the mechanical energy required to turn the handle is partially transformed into electrical energy. This is apparent in the sparks which may be drawn from the machine. Another kind of machine, which we may here mention, but which will be more fully referred to in another lesson, is the dynamo. Mechanical energy is required to drive a dynamo, and electrical energy is obtained from it.

RE-TRANSFORMATION.

We will now point out how this electrical energy may be re-transformed into energy of its original form. If we take a dynamo and set it in action by the use of mechanical energy we are able to get from it electrical energy, and this electrical energy may be used to actuate a machine called an electro-motor, which will in its turn give out mechanical energy. We have thus mechanical energy producing electrical energy, and this same electrical energy reproducing mechanical energy. This we may term an energy cycle, and illustrate it by the following diagram. Fig. 1 M is the mechanical generator; EE is the electrical energy; EM is the electro-motor; and ME is the mechanical energy.

We must be careful to note that in this transformation and re-transformation, much of the energy used to start with is lost in the process, and the diagram is intended to show this. Let 100 represent the value of the mechanical energy supplied to M; 75 may be taken as the value of the electrical energy of EE, supplied to the electro-motor EM, and 50 as the value of the mechanical energy of ME. We thus have only one-half the original energy available on re-transformation, and frequently in actual practice the proportion is still less.

Secondly (*b*), of *Chemical Energy*. Take a cylindrical glass vessel containing dilute sulphuric acid, and introduce therein a strip of copper and a strip of zinc, both of which have been previously well cleaned. Do not let the strips of metal touch one another either inside or outside the vessel. If we watch the metals and the solution we shall not be able to see any evidence of chemical action going on. But now let us connect the metals together on the outside by

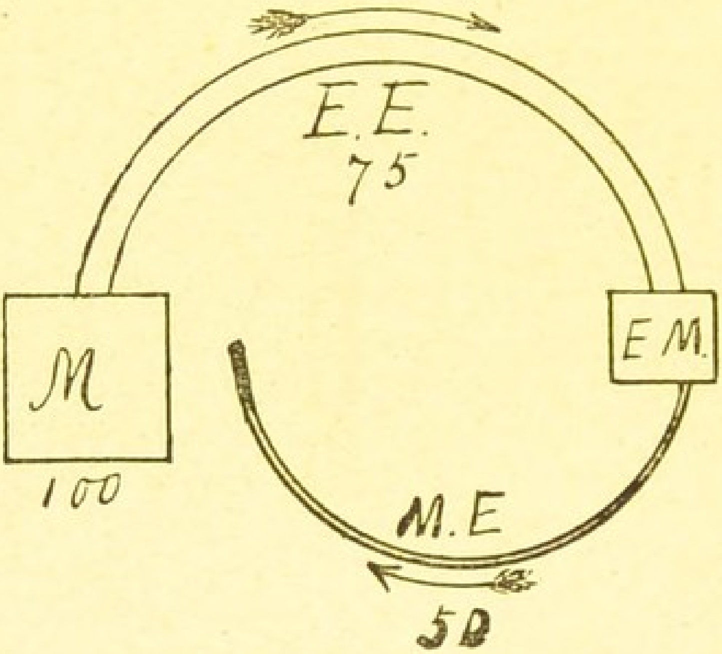

FIG I.

a wire, and a violent chemical action is at once apparent in the vessel. Bubbles of gas are seen to rush across that portion of the solution which is between the metals from zinc to copper. Some of the bubbles rise to the surface and others adhere to the latter metal. The zinc is being decomposed, and, if allowed to remain long in the solution, would he quite eaten up. Let us now introduce in the outer connecting wire a galvanometer (which is an instrument specially constructed to indicate the presence of and measure electric currents, and of which more will be said hereafter), and we shall find a distinct deflection of the needle. This indicates the presence of an electric current in this outside wire. Or, let us bring near the wire a simple magnetic compass needle. The needle will be violently agitated, and thus give us another proof of the presence of an electric current.

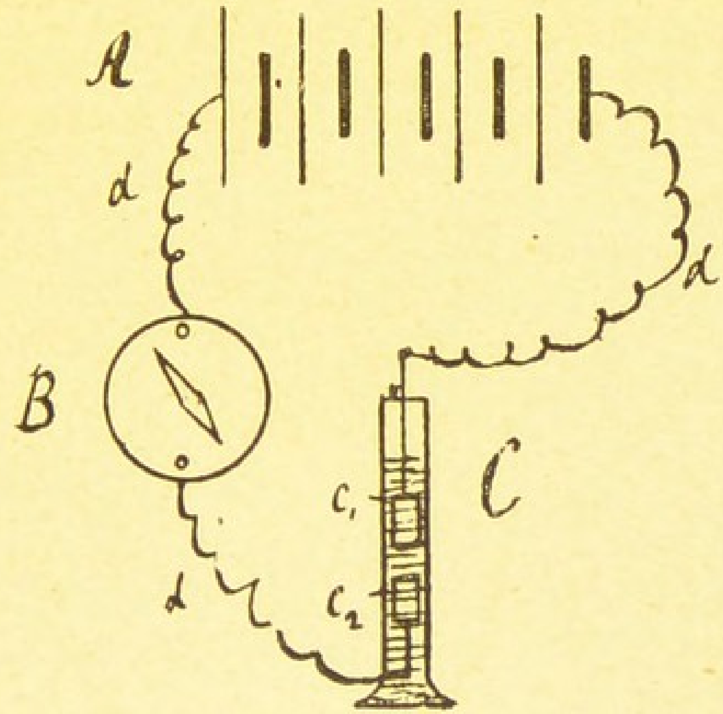

FIG. 2.

We have then in this arrangement (see Fig. 5), which is known as the simple voltaic cell, distinct evidence of chemical energy producing or being transformed into electrical energy. The chemical energy at work inside the vessel, or rather a portion of it, is transformed into electrical energy outside the cell. The electrical energy thus obtained may also be re-transformed into energy of its original form. To do this take several of such voltaic cells, arranged with the zinc of one connected to the copper of the next. Connect the copper of the first cell and the zinc of the last to metal conductors of silver or platinum, which must be placed a short distance apart in a glass vessel, containing ordinary tap water. As soon as the connection is completed, chemical decomposition of the water will commence, the component gases, oxygen and hydrogen, coming off in bubbles, while the volume of water perceptibly diminishes.

Fig. 2 represents diagrammatically the arrangement of apparatus for experimental proof of the chemical energy cycle. *A* is the battery of voltaic cells; *B* is the galvanometer, showing its needle deflected; *C* is the vessel containing water, in which the silver or platinum conductors, c_1 and c_2 are placed; *d*, *d*, *d* are conducting wires.

This process is called the electrolysis of water, and is best carried out with the aid of an apparatus called a voltameter, in which the gases can be collected and tested separately (see Fig. 27).

Here, again, we have an energy cycle completed. Chemical energy is transformed into electrical energy, and this in turn is re-transformed into chemical energy. We again have much loss of energy in the process.

Thirdly (*c*), of *Thermal Energy*. Take two strips of dissimilar metal, and join one end of each to the other. Then apply heat to the junction, and connect their free ends together through a galvanometer. The galvanometer needle will at once be deflected, showing that the thermal energy applied to the junction of the metal strips has been transformed into electrical energy.

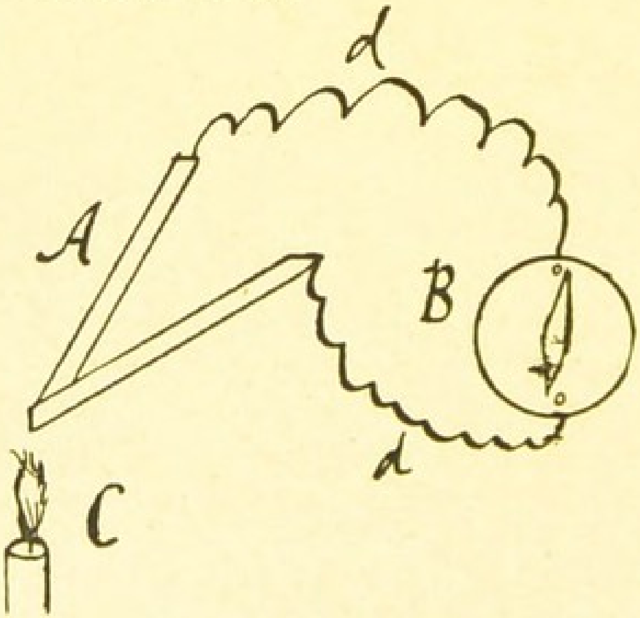

FIG. 3.

Fig. 3 represents diagrammatically a simple thermopile in action. *A* is the couple of dissimilar metals; *B* is the galvanometer showing a slight deflection of its needle; *C* is a gas or other flame engaged in warming the junction of the couple *A*; *d*, *d* are connecting wires.

This is the simplest form of thermopile. If we take a thermopile, composed of several such metallic couples properly arranged, we can ring electric bells, and have other proofs of the presence of electrical energy.

To re-transform electrical energy so obtained into its original form, we may by using a very powerful thermopile

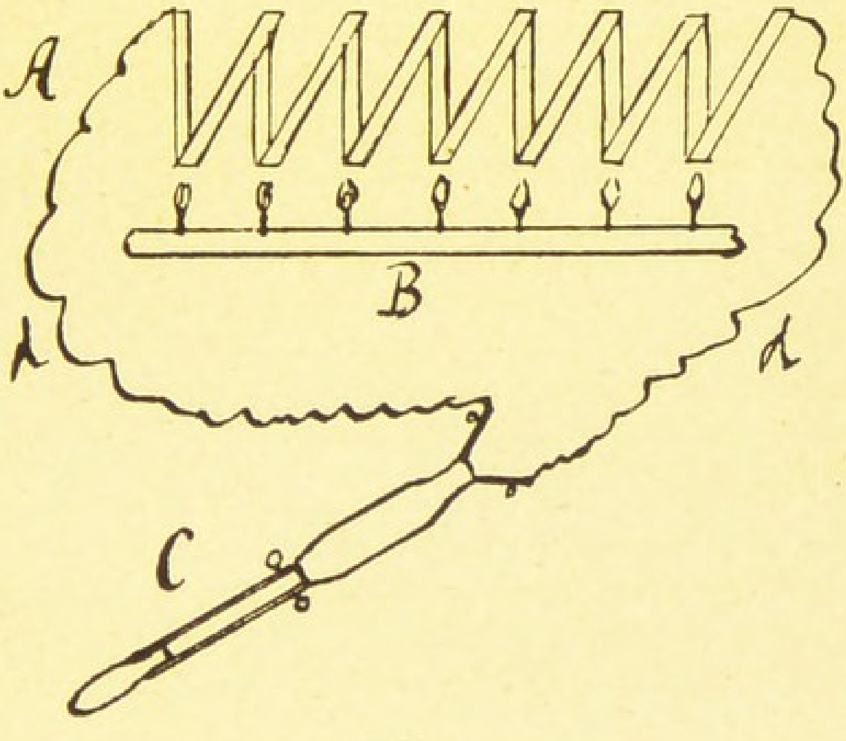

FIG. 4.

produce considerable heat. For instance, thermopiles have been used to light incandescent electric lamps, and if we attach the conducting wires of a suitably-arranged thermopile to the cautère of an electro-cautery apparatus, it will become white-hot and ready for use in the same way as if connected to its ordinary battery.

Fig. 4 represents diagrammatically the arrangement of appparatus for experimental proof of the thermal energy cycle. *A* is the thermopile of many couples; *B* is the heating apparatus; *C* is the electro-cautère; *d*, *d* are connecting wires.

Again we have completed our energy cycle. Thermal energy transformed into electrical energy, and this electrical energy re-transformed into thermal energy. Loss, however, takes place in the process as before.

LOSS OF ENERGY.

In speaking as we have done of the loss of energy we do not wish it to be understood that any energy can be really lost. It is, rather, dissipated as regards the immediate use we wish to make of it. The doctrine of the conservation of energy prohibits all idea of actual and permanent loss. When we speak, therefore, of loss of energy in its transformation from one form to another, we mean that we cannot so control the transformation that the entire change shall take place in the exact direction we desire, and that machinery and apparatus never give out in a form available for useful work all the energy put into them.

ELECTRIC GENERATORS.

The transformation of energy into electrical energy is usually known as the generation of electricity, and the apparatus or machines by which the change is effected are called electric generators.

We have, therefore, referred to three classes of electric generators—(*a*) mechanical, (*b*) chemical, and (*c*) thermal.

SIMILARITY OF ELECTRIC CURRENTS.

It is sometimes supposed that the electricity generated by the different kinds of generators is not the same, but this is an error. Exactly the same kind of work may be done by electricity generated mechanically as by that generated chemically or thermally, provided the generators are suitably constructed.

We cannot catch electricity to examine it and determine its colour, construction, and general appearance. We can only judge of it by its action, and so long as we find that electricity generated by either of the above-named classes of generators is capable of the same chemical, mechanical, thermal, and physiological action, we have no right to assume that the method of generation makes any difference in the character or quality of the electricity generated.

Wherever a current flow of electricity is set up two factors are necessarily present. These factors are electromotive force and current-strength.

The physical similarity of electric currents, however generated, lies in the presence of these two factors. The difference lies in variations of the relative value of these factors.

These internal differences (of the relative value of electromotive force and current-strength) will be considered later on; at present we desire to impress upon our readers the fact that electricity is practically the same, however generated.

It follows, then, that the source from which electricity for medical purposes should be drawn, or, in other words, the form of generator used, is to be determined by considerations of convenience and economy only.

COMPARISON OF GENERATORS.

For medical purposes we require an electric generator which shall be :—

(1) Always accessible.

(2) Easily controlled.

(3) Steady in its action.

(4) Not liable to disturbance by ordinary atmospheric changes.

(5) Not troublesome by reason of its noise or unpleasant fumes.

(6) As small as possible.

(7) Not costly to purchase or maintain.

Let us see how far the classes of generators above referred to fulfill these requirements. Of the mechanical class we will take the dynamo, passing over for the present the frictional or other static machine. A dynamo may be expected to fulfil conditions 1, 2, and 4, but not the others. It requires to be driven by a steam, gas, or water engine ; is costly to purchase and maintain ; generally involves noise (by its motor engine), and moreover generates far larger quantities of electricity than are required for electric treatment in most Hospitals. Given an establishment with many patients requiring electric treatment, and electricity required also for other purposes, such as light and power, it might well be that a dynamo driven by an engine would be the best form of generator to use ; but extreme care would be necessary to get condition 3 fulfilled. A dynamo current may be quite steady enough for such purposes as light and power, but far too unsteady to be used with safety upon the human body. Steadiness in action is a most important condition, and as the fire, the engine, the belting, and the dynamo itself, each and all form separate possible sources of irregularity, we do not consider it advisable under any circumstances to draw current direct from a dynamo for Medical purposes. If accumulators or secondary batteries be interposed the condition is very much improved, but these belong more properly to the chemical generator class.

The thermopile may fulfil conditions 1, 4, and 6, possibly 7 also, but it is difficult to control, seldom steady in its action for long, is almost sure to give off unpleasant fumes, and is costly both to purchase and maintain. To obtain currents of useful strength very many pairs of metals must be used, and their arrangement for efficient working renders it very difficult to reach and repair any of the couples which may get out of order. Consequently the difficulty of control and cost of maintenance are very great.

Until the thermopile be much improved, therefore, we cannot consider it a suitable generator of electricity for Medical purposes.

Chemical generators usually fulfil conditions 1, 2, 3, 4, 5, in part 6, and in some cases 7. They are very far from perfect in the way in which they fulfil these conditions, as we shall have to show in the next lesson ; but as matters stand, chemical generators are the most convenient to use for Medical purposes

LESSON II.

Chemical Electric Generators—Cells: Simple Voltaic, Leclanché, Silver Chloride, Daniell, Minotto, Bichromate, Grove, Bunsen—Secondary Cells or Accumulators—Batteries Arranged in Series and in Parallel.

WE finished our last lesson with the consideration of the relative advantages and disadvantages of the different classes of electric generators, and arrived at the conclusion that for Medical purposes those belonging to the chemical class are most suitable. We have now, therefore, to turn our attention to

CHEMICAL ELECTRIC GENERATORS.

These vary much in form, construction, and the chemical agents employed. There are, however, certain general qualities which it is advisable that all chemical electric generators should possess. They may be briefly summarised as follows :—

1. High electro-motive force (written for brevity, E.M.F.).
2. Constancy.
3. Low internal resistance.
4. Absence of internal action when at rest.
5. Cleanliness.
6. Freedom from noxious or corrosive fumes.

Chemical generators are usually composed of one or more cells. A single cell is generally termed a *cell*, but two or more cells constitute a battery. We will first consider different types of single cell, and then deal with them when constituting batteries.

The single cell of a chemical electric generator is sometimes arranged in one containing vessel or jar only, sometimes in more than one. These containing vessels or jars are often called cells, but as this is apt to lead to confusion, we propose in these lessons to speak of them as jars, leaving the word "cell" to mean a single complete chemical electrical generator, whether composed of one or more jars.

The simplest form of cell is that known as the simple voltaic cell, and referred to as such in Lesson I. It was invented by Volta, a Professor in the University of Pavia, about one hundred years ago, and consists of a vessel of glass, earthenware, or similar substance, containing a weak solution of sulphuric acid. In the solution a strip of copper

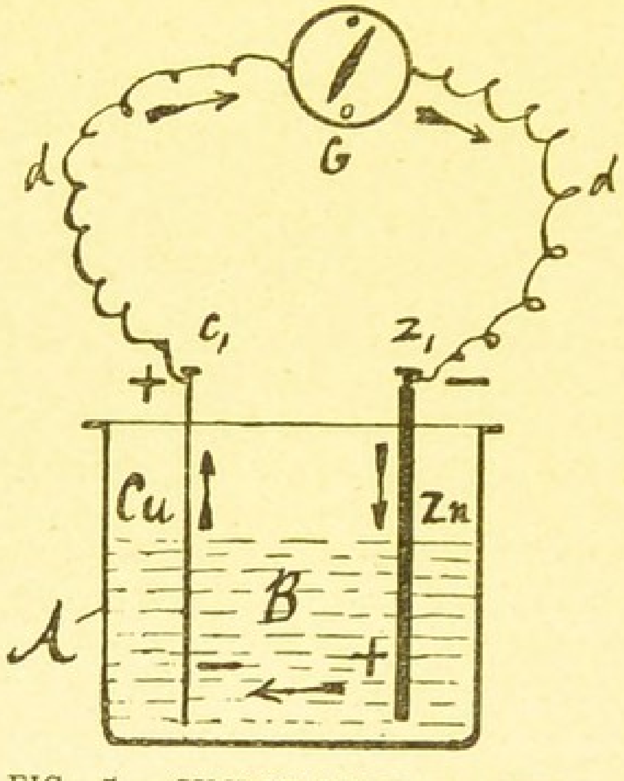

FIG. 5.—SIMPLE VOLTAIC CELL.

and a strip of pure zinc (which have been previously well cleaned) are placed so that they are not in contact with each other. A piece of copper or other conducting wire is attached to the top of each metal strip, and the cell is ready for use.

Fig. 5 represents diagrammatically a simple voltaic cell in action. A is the containing vessel or jar, B is the exciting solution, *Zn* is the zinc plate, C*u* the copper plate, c_1 is the positive pole, z_1 the negative pole, G is the galvanometer connected by the wires *dd*.

The chemical reaction that takes place is shown by the following equation :—

$$Zn + H_2 SO_4 = Zn\ SO_4 + H_2 ;$$

or in words, zinc and sulphuric acid become sulphate of zinc and hydrogen. The zinc enters into combination with the radical of the acid and turns out the hydrogen. The sulphate of zinc produced in the reaction remains in solution, while the hydrogen escapes in bubbles, which may be seen sometimes lightly adhering to the metal strips, sometimes rising to the surface of the solution.

The electric action starts at the zinc plate (which is gradually eaten up), and passes across the solution to the copper plate. This may be seen by putting a cell into a lantern, and showing its magnified image upon the screen while the process is going on. A strong stream of cloudy bubbles will be seen, as it were, issuing from the zinc, and passing across the fluid to the copper. The zinc is therefore called the positive metal plate, when the *internal* action of a cell has to be considered; but we must be careful not to confuse this with the positive pole of a cell or battery, for when the *external* action has to be considered, and the outer ends or poles of the metal plates have to be dealt with, the copper is positive and the zinc negative.

This is obvious when we remember that no effective electric action takes place until the elements are connected outside the cell, and the circuit, as it is called, is completed. We show this in the diagram (Fig. 5), where the zinc plate is represented by a thick line marked *Zn*, and also marked inside the excitant + or positive. The direction of the circuit is shown by the arrows; and following these we see that it passes inside the cell from zinc to copper, and outside from copper to zinc. The part of the circuit from which we obtain electricity for useful work is manifestly the *external* portion, so that where the use of electric currents from a cell or battery is concerned, the copper is positive and the zinc negative.

The outer ends or terminations of the elements are called poles, and it is to these poles that the conducting wires are fixed, by means of which the current flows, or is assumed to flow, out from and back to the cell or battery. Inside the cell the zinc is always the *positive plate*, but outside its end or termination is always the *negative pole.*

This simple cell is not of much practical use, because it fails to fulfil several of the conditions named above as necessary for an efficient chemical electric generator. Let us take them in order :—(1.) Its E.M.F. (of which we will say more presently) is only moderate (about one volt). (2.) It is very inconstant both as regards E.M.F. and current strength. (3.) Its internal resistance, while fairly low to start with, soon becomes much greater by reason of local action set up by impurities in the metals and acid used. (4.) Considerable action goes on inside the cell when it is at rest, so that both the zinc and the acid of the solution are soon used up. (5) and (6) are fairly fulfilled ; but as these relate to convenience rather than electrical efficiency, they are of less importance than the others. The simple voltaic cell, therefore, had to be improved upon before the principle of Volta could be put to much practical use. Many forms of cell have been devised, some good for one purpose and some good for another. Bearing in mind that we are dealing solely with generators for medical work, we will only describe those forms of cell which are most useful for that purpose.

All such cells have for their essential parts two strips, plates, or other suitably shaped pieces of metal or similar substance, called the *elements*, and one or more exciting fluids called *excitants.*

The 'metals' used are various ; though zinc always forms one of the pair, the other is generally carbon or copper, but is sometimes silver, platinum, tin, iron or gold. The zinc must be either *pure* or *amalgamated with mercury.* The exciting fluid is either saline or acid. Of the saline fluids, solutions of sal ammoniac and of chloride of sodium (ordinary salt) are the most common. Of the acid fluids, solutions of sulphuric, hydrochloric and nitric acids are generally adopted.

We will arrange the different forms of cell under headings showing the kind of exciting fluid used thus—

A.—Cells with saline solution.

B.—Cells with acid solution.

Under A we place (I.) Leclànché, (II.) Silver chloride, (III.) Sulphate of mercury cells.

Under B (I.) Daniell, (II.) Bichromate, (III.) Grove, and (IV.) Bunsen cells, to which may be added (V.) Secondary cells, or Accumulators.

A.—(I.) The Leclànché cell has for its elements zinc and carbon, together with powdered binoxide of manganese, and for its excitant a saturated solution of sal ammoniac (ammonium chloride), or sodium chloride. These are arranged usually in two jars, one within the other. The outer jar is generally of glass for large cells, but may be of properly prepared wood, porcelain, or vulcanite, and contains the excitant, together with the zinc element, and has also standing within it, and surrounded by the excitant, the inner jar or pot, which is of a porous nature, and contains a strip or block of carbon surrounded by the powdered binoxide of manganese.

The Leclànché cell is also made with only one jar, the binoxide of manganese being applied in a conglomerate mixture attached to the surface of the carbon elements. The porous inner jar or pot is thus not needed. This arrangement is known as the agglomerate form of Leclànché's cell.

Fig. 6 shows an outline sketch of a Leclànché cell. A is the outer jar, B the inner porous jar, C the carbon element surrounded with binoxide of manganese, *Zn* is the zinc element, c_1 is the positive pole, and z_1 the negative pole. D shows an agglomerate block for use in the place of the porous jar B.

The chemical reaction of this cell is shown by the equation—

$$Zn + 2\,N\,H_4\,Cl + 2\,Mn\,O_2 = Zn\,Cl_2 + H_2O + 2\,N\,H_3 + Mn_2\,O_3.$$

That is to say, the ammonium chloride is decomposed and zinc chloride formed, while the hydrogen set free reduces the manganese dioxide.

The E.M.F. of the Leclànché cell is about 1·4 volt, so

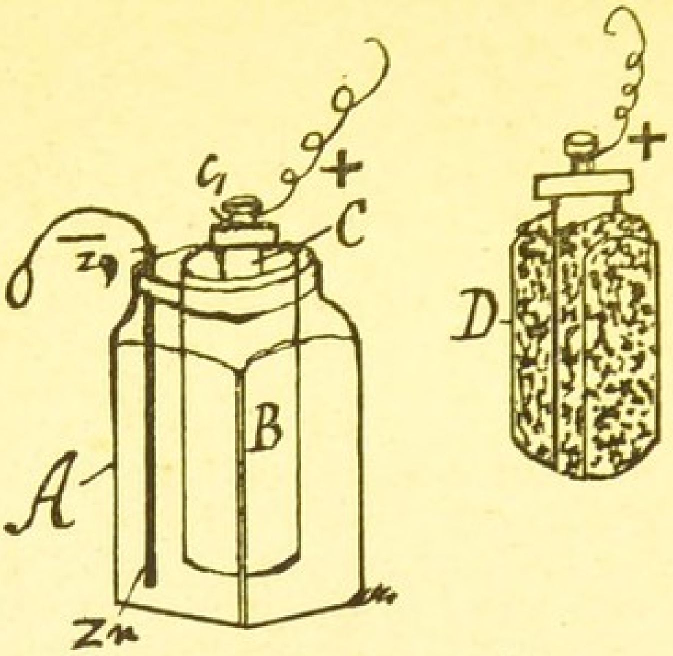

FIG. 6.—LECLANCHE CELL.

that it fairly fulfils condition 1. When required to work only a short time it is nearly constant, and as medical purposes generally only require currents for a short time condition 2 is fulfilled. Further, as this cell possesses the power of recovering itself by reason of the presence of excess of binoxide of manganese (which yields up oxygen to unite with the hydrogen bubbles), it is specially suited to work which requires a constant current for a short time at frequent and irregular intervals. Condition 3 is not well fulfilled, for when the porous jar or pot is used the internal resistance is considerable, but in the agglomerate form, where this inner jar is dispensed with, the internal resistance is much reduced. There is no internal action when at rest, so that condition 4 is satisfied; 5 and 6 are also fairly fulfilled.

There are many forms of Leclànché cell and special adaptations of it to medical batteries by many makers. It would be needless and probably quite useless to attempt to enumerate and describe them. Any student who has grasped the main principles upon which the Leclànché type of cell is arranged, will have no difficulty in recognising any variation of the type.

(II.) The silver chloride cell has for its elements silver chloride and zinc, and for excitant zinc chloride or sodium chloride. It is generally made up of very small cells. The one containing vessel or jar is usually of vulcanite or glass. The silver chloride in a granular form (to increase its surface area), is fixed in a porous bag or case, whilst the zinc is in the form of a flat rectangular plate. The elements are tied together by indiarubber bands, but are separated from actual contact by means of a pad of blotting-paper, which pad is saturated in the excitant. Its E.M.F. is about 1·2 volt, and conditions 3, 4, 5, and 6 are well fulfilled, but 2 is not.

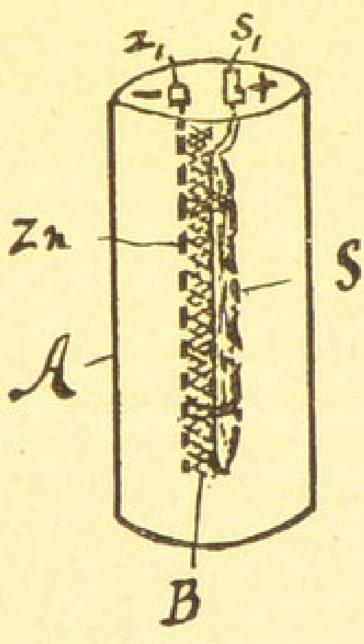

FIG. 7.—SILVER CHLORIDE CELL.

Fig. 7 shows in outline a chloride of silver cell as arranged by Gaiffe, of Paris, for pocket coil work. A is the containing vessel, B the porous pad saturated with the exciting solution, S is the silver chloride element, Zn is the zinc element, s_1 is the positive pole, and z_1 the negative pole.

This form of cell is useful for portable batteries in connection with small induction coils, as they are effective when made quite small, and can be carried in the pocket with perfect safety.

(III.) The sulphate of mercury cell, sometimes called after the inventor the Marie-Davy cell, has for its elements zinc and carbon, and for excitant sulphate of mercury. The single jar contains a mass of the sulphate, into which the carbon dips. Water is poured on, so that the salt slowly dissolves. When the cell is in action the mercury sulphate is broken up, and mercury in metallic form is deposited on the surface of the carbon.

As regards our conditions—(1) Its E.M.F. is 1·5 volt; (2) it is not constant; (3) internal resistance is small; (4) there is very little, if any, action when at rest; (5) it is fairly clean; and (6) does not give off fumes.

This form of cell is much used by some makers in constructing medical batteries, but unless the solution be very frequently renewed the cell is of very little use. Its need for constant attention and renewal of the excitant is a serious drawback.

B.—(I.) The Daniell cell has for elements zinc and copper, and for excitants dilute sulphuric acid and sulphate of copper. It has two jars. The inner contains the zinc, standing in the dilute sulphuric acid; the outer contains the copper, standing in the copper sulphate solution, having also a few crystals of the sulphate just dipping into the solution to keep up its strength.

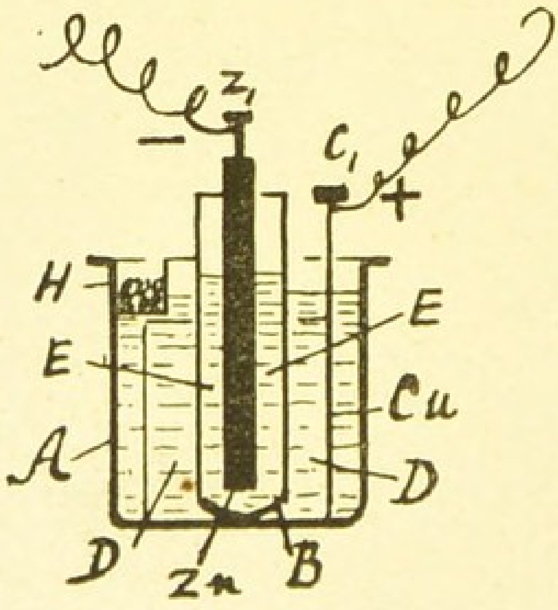

FIG. 8.—DANIELL'S CELL.

Fig. 8 represents a Daniell cell in section. A is the outer jar, B the inner porous jar, *Cu* is the copper element standing in the sulphate of copper solution D, *Zn* is the zinc element standing in the sulphuric acid solution E, H is a tray containing a few sulphate of copper crystals, c_1 is the positive pole, and z_1 the negative pole.

The chemical reaction is shown by the following equations :—

$$Zn + H_2SO_4 = ZnSO_4 + H_2 \text{ (inner jar).}$$
$$H_2 + CuSO_4 = H_2SO_4 + Cu \text{ (outer jar).}$$

The way in which this cell fulfils the conditions named is—(1) Its E.M.F. is low (equal to one volt); (2) it is very constant; (3) internal resistance is rather high; (4) its in-

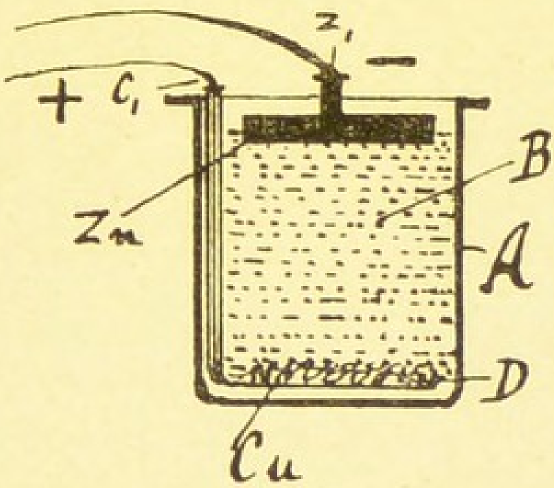

FIG. 9.—MINOTTO CELL.

ternal action when at rest is very small; (5) it is clean; (6) gives off very little in the way of noxious fumes. There are many modifications of the Daniell cell, one of the chief of which is the Minotto, in which the copper element—in the form of a plate fitting loosely to the shape of the jar—is placed at the bottom together with a few copper sulphate crystals. Piled upon it is sawdust or sand till the jar is nearly filled. This absorbent medium is then saturated with dilute sulphuric acid, and the zinc element—which must also be of suitable shape—is placed on the top.

Fig 9 represents a Minotto cell in section. A is the containing jar, B the sawdust or other absorbent saturated with dilute sulphuric acid, *Cu* is the copper element covered with the sulphate of copper crystals D, *Zn* is the zinc element, c_1 is the positive pole, and z_1 the negative pole.

We have thus an arrangement which allows us to dispense with the inner jar, and which is fairly portable. The absorbent prevents the fluid spilling, while at the same time it does not interfere with its action as an excitant.

The internal resistance of the Minotto cell is very considerable.

B.—(II.) The bichromate cell, which was invented by Poggendorf, has for its elements zinc and carbon, and for excitant a solution of bichromate of potash and sulphuric or hydrochloric acid (the latter being the best). The single jar is generally of glass or porcelain and contains the solution into which the elements dip. As, however, the excitant will continue to act upon the zinc when the external circuit is open, these cells are usually supplied with some simple mechanism to enable the zinc to be raised out of the solution when the cell is not in use.

Fig 10 is a diagrammatic sketch of a bichromate cell arranged in the form frequently adopted for working medical coils. A is the jar. B is the exciting solution. D is an insulating and close-fitting lid or stopper. C is the carbon element in two plates. *Zn* is the zinc element attached

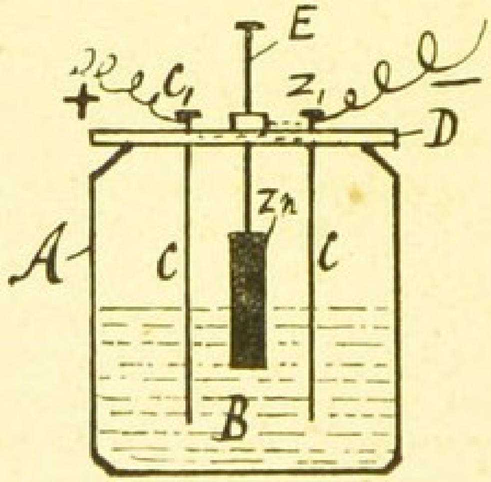

FIG. 10.—BICHROMATE CELL.

to the movable rod or pin E, which is in metallic contact with the negative pole z_1; c_1 is the positive pole to which *both* carbon plates are attached. When the cell is not in use the zinc is raised out of the excitant by means of the rod E. In the drawing the zinc is shown only half immersed in the excitant, but when the full power of the cell is required it should be completely immersed.

Owing to the fact that the combinations of chromium are complicated and easily disturbed by conditions of temperature and saturation, it is difficult to state exactly what the chemical re-action is.

This cell has (1) the high E,M.F. of 2·0 volts; (2) but is not constant; (3) its internal resistance is low; but (4) there is great internal action when the cell is not at work; so much is this the case that the zinc must always be removed when not in use; (5) it is clean; but (6) gives off slightly unpleasant fumes.

B.—(III.) The Grove cell has for its elements zinc and platinum, and for excitants nitric acid and dilute sulphuric acid.

There are two jars. The outer contains dilute sulphuric acid and the zinc element; while the inner, which is porous, contains the platinum or platinum foil dipping into strong nitric acid.

Condition (1) is well fulfilled, as the E.M.F. is 1·9 volt; (2) is also good, for the cell is very constant (for the time the solution lasts). The hydrogen liberated in the outer jar, passing through the inner jar to the platinum element, decomposes the nitric acid, is itself oxidised and produces water and nitric peroxide gas, which forms no film upon the platinum element, and so does not interfere with the electric constancy of the action; (3) its internal resistance is low; (4) it is not without internal action when at rest, but such action is small as compared with that of the bichromate cell; (5) owing to the use of such acids, it can hardly be called cleanly; (6) the strong fumes given off from the nitric acid in the form of nitric peroxide gas render this cell very objectionable under ordinary circumstances of medical work.

B.—(IV.) The Bunsen cell is very similar to the Grove, but the elements are zinc and carbon. This combination gives about the same E.M.F. as the other, but the Bunsen cell is notoriously difficult to keep in order.

(V.) Secondary cells, Storage cells, or Accumulators, do not properly belong to any class of electric *generators*, for energy must be put into them in the same form as it is afterwards obtained from them. That is to say, we charge them with electricity in order that we may obtain electricity from them.

The word *accumulators* is rather a misnomer and is also misleading. These cells do not accumulate electrical energy in the sense of being able to give out more than they receive. On the contrary they are no exception to the rule laid down in Lesson I., regarding the loss of energy always involved by the use of apparatus or machinery, and therefore they give out less than the total energy put into them. They are *secondary* cells, because they do not generate electricity, but require to be charged with it from some *primary* source. They are *storage* cells, because when charged they will hold and retain ready for use at any time in the reasonably near future the charge given to them.

These cells consist of a vessel of glass or other suitable material, containing two or more plates or sheets of lead placed close together, but not in actual contact, dipping into dilute sulphuric acid. The lead plates are specially prepared, and are such that when a current of electricity of sufficient strength is passed the positive plate becomes peroxidised, while the negative plate is deoxidised, by the hydrogen which is liberated. The plates remain in this condition till the electric current is drawn off from them, but as soon as the two lead surfaces are reduced to a state of chemical inactivity the supply of current ceases.

The E.M.F. of these cells is two volts. They are mainly useful in medical work when a perfectly steady and constant current of considerable strength is required for a prolonged period. By their use currents generated by a dynamo may be rendered perfectly safe and convenient for medical use. Secondary cells are, however, costly to purchase, and costly to maintain, inasmuch as they must be frequently re-charged, and require very special care and attention in their management.

BATTERIES.

An electric battery may consist of one or more cells. When one cell alone is used, it may fairly be termed a battery, but the word battery is generally taken to mean several cells grouped together, and electrically connected in such manner as shall best suit the conditions of the work they are required to perform.

When the cells of a battery are connected together, with the negative pole of one cell in contact with the positive pole of the next, or *vice versa*, and so on to the end, they are said to be connected in *series*.

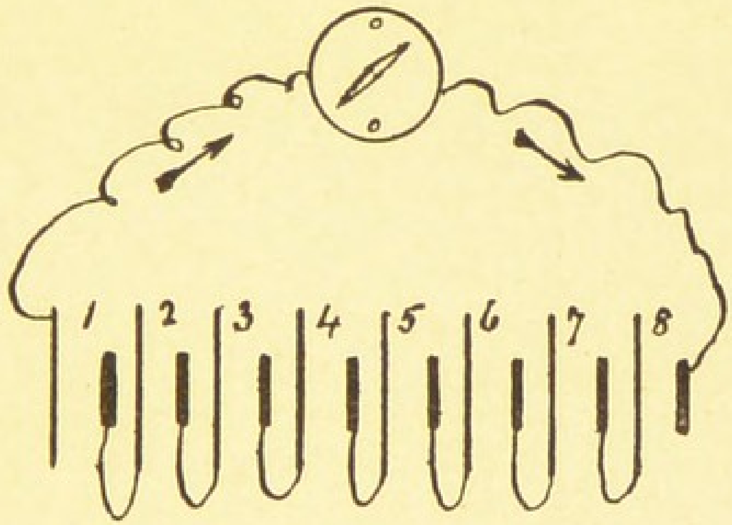

FIG. 11.—BATTERY (CELLS IN SERIES).

Fig. 11 is a diagram showing eight cells connected together in *series*, thus forming a battery having an E.M.F. equal to the sum of the E.M.F.'s of all the cells. For instance, if each of these cells has an E.M.F. of 1·5 volt, the total E.M.F. of the battery is 12 volts.

NOTE.—In these diagrams it is customary to represent the cell by lines, one thick and one thin line to each cell.

The thick line should always be taken to represent the zinc in these lessons.

When the cells are connected, with the negative pole of one cell in contact with the negative pole of the next, and the positive of one cell to the positive of the next, and so on to the end, they are said to be connected *in parallel* or in *multiple arc.*

Fig. 12 is a diagram of six cells connected in parallel or multiple arc, thus forming a battery having an E.M.F. equal to that of *one cell only*, but capable of giving large current strength.

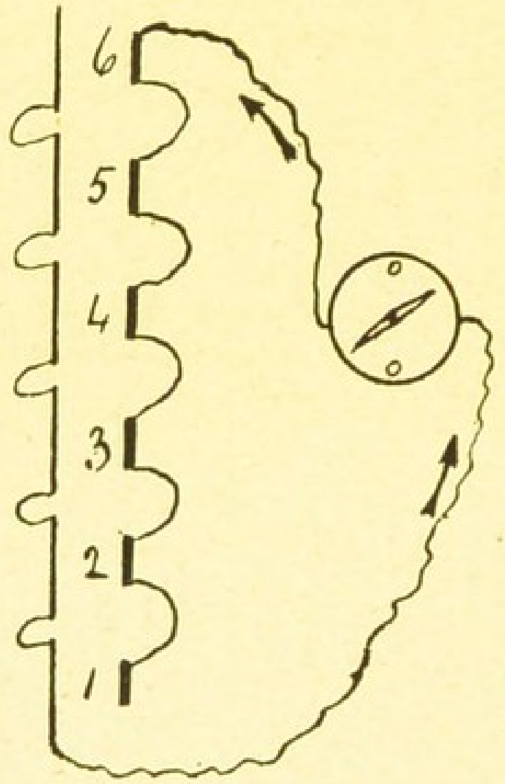

FIG. 12.—BATTERY (CELLS IN PARALLEL OR MULTIPLE ARC).

The cells of a battery are sometimes connected in groups, two or more in parallel in each group, and the groups in series.

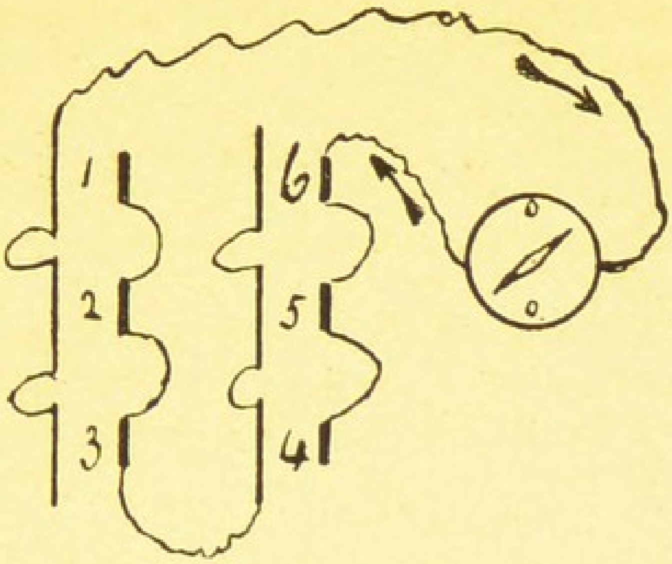

FIG. 13.—BATTERY (CELLS IN GROUPS).

Fig 13 is a diagram of six cells connected in two groups of three each. The cells of each group are connected in *parallel*, and the groups are connected in *series*. A battery is thus formed having an E.M.F. equal to that of two cells, and capable of giving considerable current strength.

The practical use of arranging batteries in different ways will be shown more fully after the terms E.M.F., Current-strength, and Resistance have been explained.

LESSON III.

Electric-Motive Force—Current Strength—Resistance—Ohm's Law—Definition of Terms.

AS indicated in Lesson II., all current flow of electricity involves two factors, which are termed respectively electro-motive force and current strength.

ELECTRO-MOTIVE FORCE

depends upon difference of potential at the poles of the generator. It is analogous to the differences of pressure at the two ends of a water-pipe necessary to produce a flow of water through the pipe, and is that by reason of which the electric current flows, or is driven through or along a conductor.

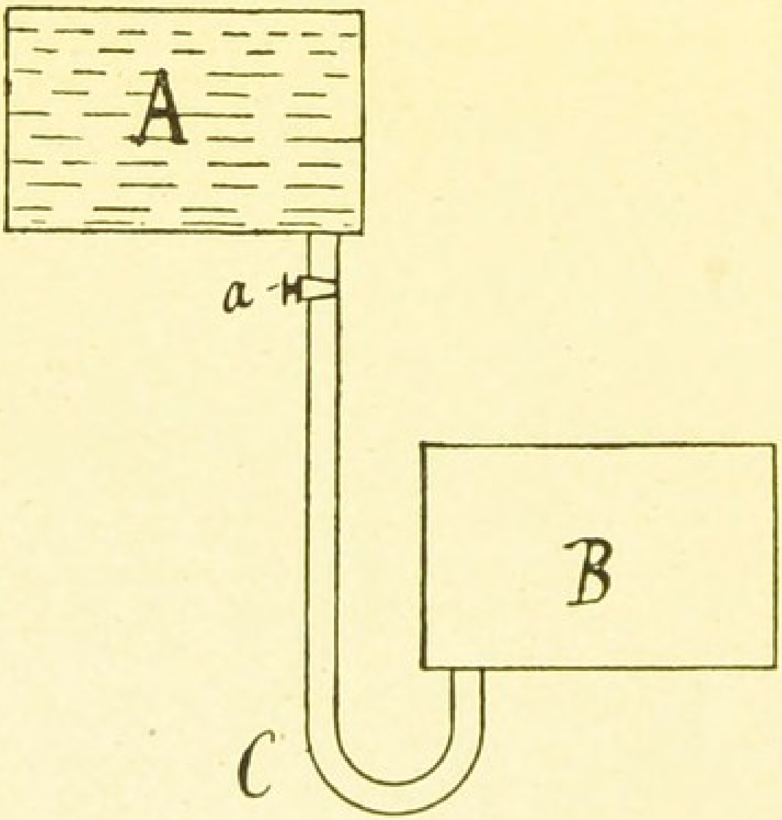

FIG. 14.

If, for instance, we have two vessels, A and B, at different levels (as shown in Fig. 14), connected together by the pipe C, A being filled with water, B remaining empty, and the stopcock *a* shut off, it is manifest that while the apparatus is thus arranged, the condition is one favourable to the flow of water from A to B through C so soon as the stopcock *a* is opened. While *a* remains closed, there can be no flow through C, however great the difference of level between A and B. The difference of level exists

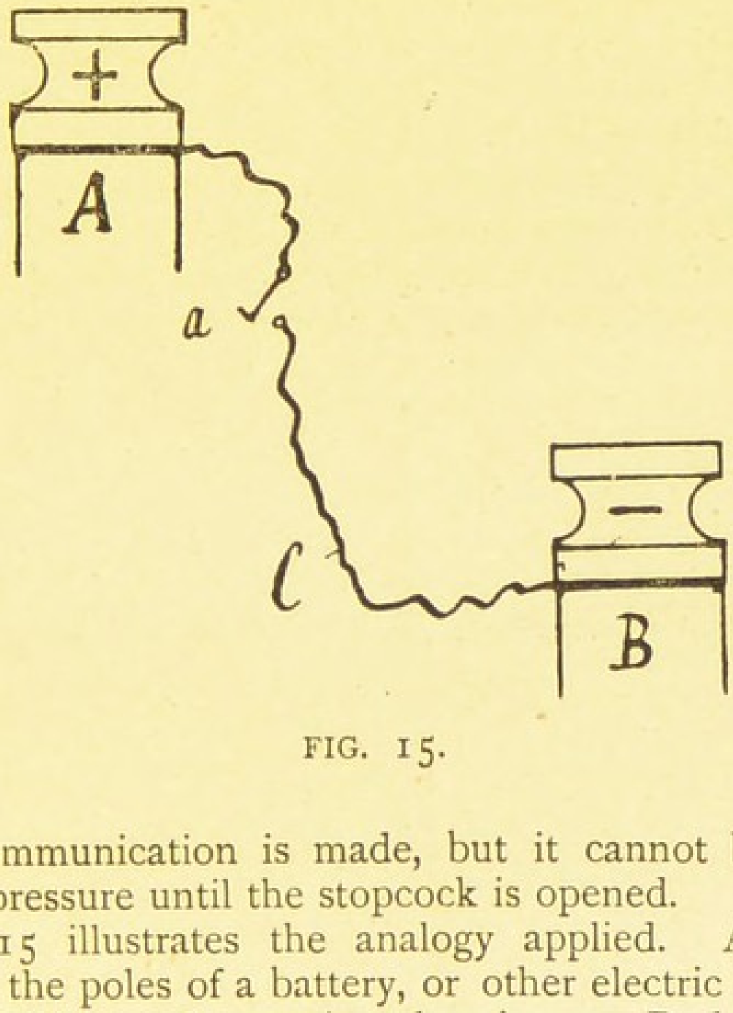

FIG. 15.

before communication is made, but it cannot be said to produce pressure until the stopcock is opened.

Fig. 15 illustrates the analogy applied. A and B represent the poles of a battery, or other electric generator; A is the positive pole carrying the sign +, B the negative pole carrying the sign —; C represents the connecting wire or other conductor through which direct communication can be made; *a* is a switch or key by means of which the electric connection between A and B is completed. A and B, in electrical phraseology, are said to be at different potentials, corresponding to the difference of level in the water pipes. Directly the connection is completed by closing the switch *a*, electro-motive force resulting from the difference of potential comes into play and drives the electric current on its way.

CURRENT STRENGTH.

The quantity of electricity flowing through or past any point in a conductor during any given time is designated the current strength, or more shortly "the current." As, however, we desire to avoid all risk of confusion regarding the terms involved, we prefer to call this factor in the current flow *current-strength.*

The quantity of water flowing at any time in any part of the pipe C corresponds to the current strength.

As pressure *and* quantity of water are needed to produce a flow of water, so both electro-motive force *and* current-

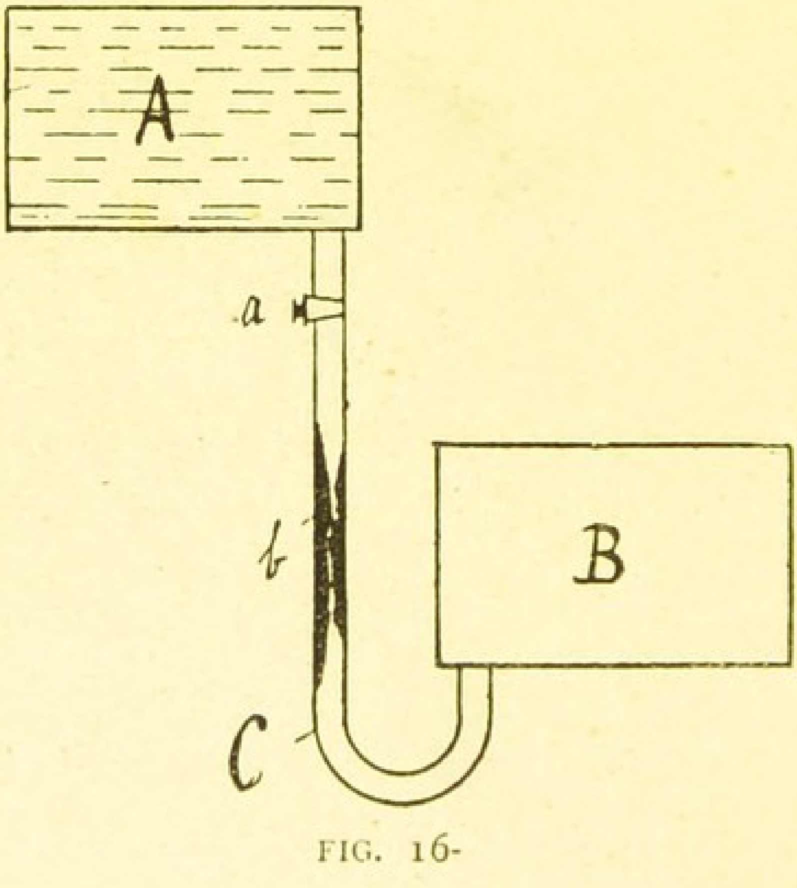

FIG. 16-

strength are necessary to produce a flow of electricity. We must not forget the necessary presence of these two factors in all currents of electricity. They may, and often do, vary enormously relatively to one another. We may have great electro-motive force and small current-strength, or *vice versa*. We may have them both great or both small, and so on, but they are both always present.

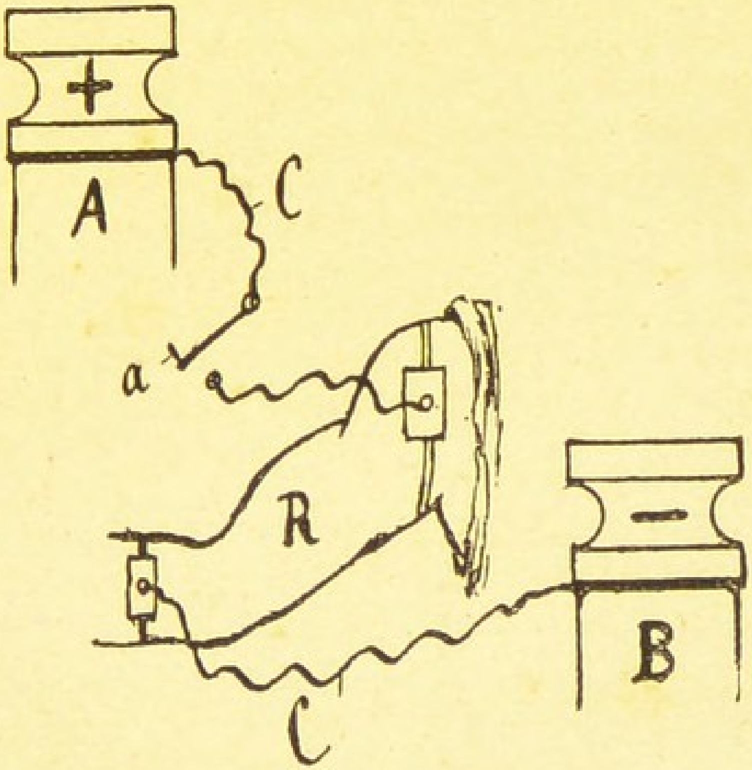

FIG. 17.

RESISTANCE.

Any obstruction offered to the flow of electricity is called resistance, and is somewhat analogous to the resistance to flow of water offered by friction in the pipe, or by other obstructions, partial or entire.

Fig. 16 represents an obstruction in a water-pipe, which is analogous to electric resistance. A and B are water vessels as before. C is the connecting pipe, and *a* the tap; *b* is an obstruction in pipe C, which obviously hinders the free flow of water from A to B, so that though the *pressure* due to difference of level between A and B remains as before, only a small *quantity* of water will pass at any given time. The presence of obstruction *b* does not alter the pressure, but it does considerably alter the quantity which can flow.

Fig. 17 represents an electric circuit, of which a human arm forms a portion. The arm offers resistance to the flow of electricity, and corresponds to the obstruction *b* in the water-pipe arrangement of Fig. 16. A and B are the terminals of an electric generator, possessing difference of potential as before. C is the connecting wire, *a* is the key or switch, and R the resistance. The E.M.F., due to the difference of potential between A and B, remains as in the first case (Fig. 16), but owing to the resistance offered by the arm to the flow of current, only a small current-strength can pass from A to B. The presence of resistance R does not alter the E.M.F., but it does alter the current-strength.

Pressure in a water pipe is the factor which overcomes obstruction and causes flow. In like manner electro-motive force in an electric circuit is the factor which over-comes resistance in that circuit, and similarly makes the current flow. The quantity flowing depends upon the amount of resistance in the circuit.

Electric-motive force is generally written for shortness E.M.F, and we shall so write it during the remainder of these lessons. Current-strength is sometimes called current intensity, and is written for shortness sometimes C, some-times I. We prefer the former, but as that is hardly explicit enough shall adopt the symbols C-S. Resistance is represented by the capital letter R.

E.M.F., C-S, and R, can all be measured, and their units of measurement are as follows :—

E.M.F. is measured in Volts.
C-S „ „ „ Ampères.
R „ „ „ Ohms.

The ampère is too large a unit for medical purposes, so its thousandth part has (on the suggestion of Dr. de Watteville) been adopted. This medical unit of C-S is called the milliampère, written shortly *m.a.* (or γ); but we must not forget that this is only the thousandth part of the proper unit (the ampère), which has to be used in all calculations.

OHM'S LAW.

The relation between E.M.F., C-S, and R is known as Ohm's Law, and is expressed by the equation :—Current-strength in ampères equals electro-motive force in volts, divided by the total resistance in the circuit in ohms, or shortly—

$C = \frac{E}{R}$ where C stands for C-S in ampères, E. for E.M.F. in volts, and R for R in ohms.

By means of this law, when the values of any two of the symbols are known, it is easy to find that of the third, for the equation is true in whatever way it may be written. If we know the values of E and R, but want to find C, we use the equation written above. If we know the values of E and C, but want to find R, we use the equation written as $R = \frac{E}{C}$ If we know the values of C and R, but want to find E, we use the equation written as $E = C \times R$. It will be advisable to illustrate the use of Ohm's law by a few numerical examples :—

(1) How much C-S will be passed through a patient whose R is one thousand five hundred ohms, if a battery having an E.M.F. of thirty volts be used?

Ans.: $C = \frac{E}{R}$ *i.e.*, C-S $= \frac{30}{1500} = 0.020$, or 20 milliampères.

(2) What is the R of a patient through whom a C-S of eighteen milliampères is passed by a battery having an E.M.F. of twenty-five volts?

Ans.: $R = \frac{E}{C}$ *i.e.*, $R = \frac{25}{0.018} = 1380$ ohms: therefore

R of patient is 1389 ohms.

(3) If a C-S of fifteen milliampères has to be administered to a patient whose R is one thousand two hundred ohms, what amount of E.M.F. must the battery used possess?

Ans.: E = C × R, *i.e.*, E = 0·015 × 1200 = 18 volts: therefore E.M.F. of battery must be eighteen volts.

(4) If the cells of the battery used in the last example have each an E.M.F. of 1·28 volt, how many such cells must be employed?

Ans.: To find this we have only to divide the total E.M.F. required by the E.M.F. of each cell, *i.e.* $\frac{18}{1\cdot28}$ = 14 cells.

Thus we see that by using this law we may find out with accuracy many things which would otherwise be mere guess work. It tells us at a glance that it is quite useless to attempt to pass a C-S of 20 *m.a.* through a patient of normal R (one thousand two hundred ohms) with a battery of five or six cells, whose total E.M.F. cannot exceed twelve volts and is probably not more than eight; on the other hand, supposing the R of the patient to be reduced to, say, two hundred ohms by using one electrode internally, the C*s* (the same nnmber of cells being used) would be dangerously increased.

The total E.M.F. of batteries depends upon (*a*) the E.M.F. of each cell, and (*b*) the way such cells are arranged or connected up.

(*a*) The E.M.F of each cell is determined by the difference of potentials of the elements used and the character of the excitant, as we have previously shown. *The size of the elements or the size of the cell itself has no influence on the E.M.F.* A cell made in a jar as large as an oyster barrel has no greater E.M.F. than one made in a test tube, if the elements in each case be of the same materials and the excitant similar.

The idea that large cells possess greater E.M.F. than small ones is a very natural one, but it is entirely erroneous, as may easily be proved by experiment.

As shown above, E.M.F. is the factor in current flow which overcomes resistance (R); therefore if a battery of small cells will not overcome the R of the body or part thereof and pass a current through, it is equally certain that a battery of large cells (provided, of course, that the number of cells used be the same) will in like manner, fail to pass any current through the same R.

(*b*) To get the maximum E.M.F. from a battery the cells must be arranged or connected up *in series* as shown in Lesson II.

As the total E.M.F. of the battery has to overcome the total R in the circuit, of which the *internal* R of the battery forms a part, the advantage of *low internal* R is apparent.

The C-S of batteries depends upon (1) the size of the elements, (2) the activity of the excitant, and (3) the manner in which the cells are connected up.

(1) The size of the elements and the portion of their surface in contact with the excitant are the main factors controlling the C-S of a battery. Large cells having large surface area of their elements in contact with the excitant are capable of giving great C-S, and will therefore be more useful than small cells when strong currents are required. (2) The activity of the excitant has also to be taken into consideration, for a weak excitant means slight chemical action, and slight chemical action in a battery means feeble electric current. (3) Cells in series give the maximum E.M.F. and the minimum C-S, because when so connected we have the sum of all the internal R's to work against, and as C-S $= \frac{\text{the total E}}{\text{the total R}}$ any arrangement of cells which increases the total R by adding to the internal R, weakens the value of C-S. Cells in parallel give the maximum C-S with the minimum E.M.F., because by this arrangement all the positive elements become practically one, as do also all the negative elements, so that we have what is equivalent to one large cell, having consequently the E.M.F. of one cell, and an internal R represented by the reciprocal of the sum of the reciprocals of the R-s of all the cells.

Let us take an example by way of illustration—A battery of five cells, each cell having an E.M.F. of 1·2 volt, and an internal R of one ohm, is used to pass a current through an external R of a half-ohm. With the battery arranged in series our equation would be :—

$$\text{C-S} = \frac{E}{R} \text{ i.e., C-S} = \frac{5 \times 1{\cdot}2}{(5 \times 1) + 0{\cdot}5} = \frac{6}{5{\cdot}5} = 1{\cdot}09 \text{ ampère.}$$

With the battery arranged in parallel our equation would be :—

$$\text{C-S} = \frac{1{\cdot}2}{\frac{1}{5} + 0{\cdot}5} = \frac{1{\cdot}2}{0{\cdot}2 + 0{\cdot}5} = \frac{1{\cdot}2}{0{\cdot}7} = 1{\cdot}71 \text{ ampere.}$$

In this case, then, we have a C-S more than fifty per cent. greater when the cells are arranged in parallel than when they are arranged in series. But we must call attention to the fact that in this example the R of external circuit is very low, and that in practice it frequently happens that owing to the great external R five cells arranged in parallel would not possess sufficient E.M.F. to pass any current at all. The student might with advantage try a few similar examples for himself.

The ordinary medical batteries are generally arranged with fixed connections in series, and for many applications of electricity to the body this is the most convenient form of arrangement. For the electro-cautery and electro-laryngoscope, &c., it is of great advantage to be able to arrange the cells in parallel. Whenever it is required to pass a large C-S through a low R, as is the case when a cautery has to be heated, cells should be connected in parallel, but when at other times, as generally happens in medical work, a small C-S is required through a high R, the cells should be connected in series.

Having now dealt with batteries, their internal working, and the arrangement of their cells, so far as the generation of continuous currents is concerned, we proceed to give definitions of a few terms employed in their use. It will be best to arrange them alphabetically :—

ANODE.

The electrode attached to the positive pole.

CIRCUIT.

The system of conductors by means of which electricity flows out from and returns to the battery or other generator. For instance, a patient, a galvanometer, the electrodes, and rheophores, when all connected together electrically to the poles of a battery form a circuit.

CONDUCTORS.

A conductor is any substance which will allow electricity to pass through or along it. Ordinary conductors are wires of some metal, such as copper, silver, or iron. The human body is also a conductor under certain conditions.

CURRENT.

The quantity of electricity flowing through or past any point in a conductor during any given time.

ELECTRODES.

The conducting media of many and various forms which are connected to the distant ends of the reophores, and are used to conduct electricity to the patient *bv direct contact with his body.*

INSULATION.

This consists in the isolation or confinement of electric currents and charges in such a manner that they do not escape from their proper conductors. All substances which are bad conductors are insulators more or less—*e.g.*, silk, india-rubber, gutta percha, dry air, glass, wood, &c.—but none are perfect insulators. The difference between the conductivity and insulating power is one of degree only. A substance which might be a fairly good *insulator* for a current of low E.M.F. might be a fairly good *conductor* for one of high E.M.F.

KATHODE.

The electrode attached to the negative pole.

RHEOPHORES.

The flexible conducting wires which conduct electricity from the terminals of the battery or switch board.

SWITCH BOARD.

The board usually placed at the top or front of a medical battery (but which may be quite separate) on which the knobs, buttons, screws, switches, &c., are placed, and from which electricity may be taken to a distance from the battery. This is sometimes incorrectly termed the *element board*. A useful form of switch-board is shown in Plato I., which is taken from one in use at the Institute of Medical Electricity, 35, Fitzroy Square, London, W.

TERMINALS.

The termination of the wires which conduct electricity from the cells to the switch-board. They are sometimes called binding screws, or binding posts.

In bringing this lesson to a close we desire to call attention to the fact that we have so far dealt with the generation and control of continuous currents only. Other forms of current and their generation will be considered in a future lesson, but at present we content ourselves with the consideration of the continuous current drawn direct from the battery.

PLATE I.

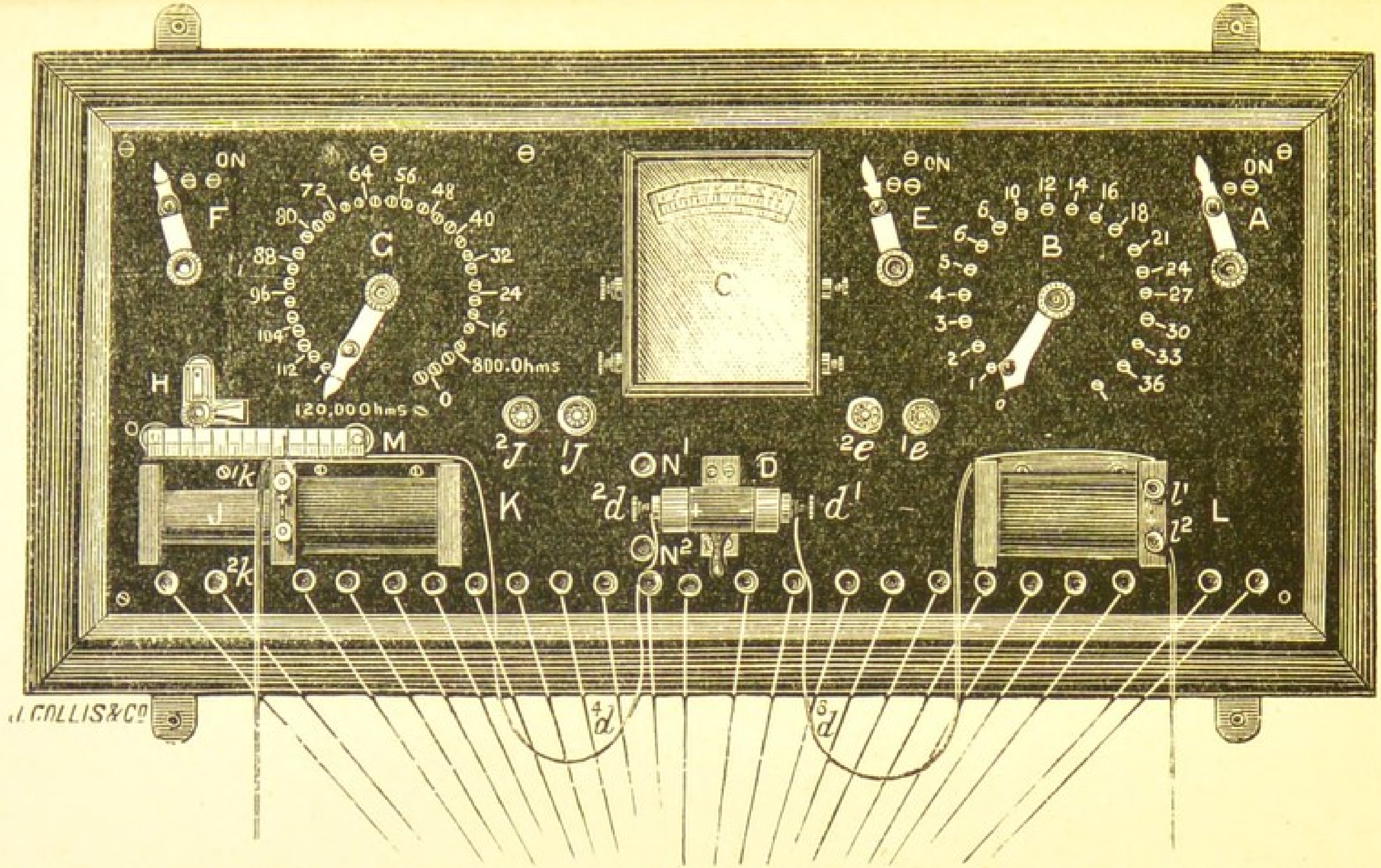

FIG. 1.—A, switch for the continuous-current circuit; B, dial collector for controlling number of cells in circuit; C, galvanometer, graduated in milliamperes, and always kept in circuit with the patient when continuous current is administered; D, current reverser—d^1 and d^2, terminals of the continuous-current circuit, d^3 and d^4, flexible rheophores; E, switch of a separate circuit for lighting a small incandescent lamp used to examine cavities—e^1 and e^2, terminals of the lamp circuit; F, switch for the induction coil circuit; G, rheostat of 12,000 ohms in the primary circuit of the coil; H, contact breaker; J, primary coil—j^1 and j^2, terminals of primary coil; K, 10-ohm secondary coil—k^1 and k^2, terminals of secondary coil; L, 2,000 ohm secondary coil interchangeable with K—l^1 and l^2, terminals of 2,000-ohm coil; M, scale graduated in millimetres showing the distance the coils K or L are passed over coil J; N^1 and N^2, terminals for connecting any of the coil terminals with d^1 and d^2 so that currents from both sides of the board may be drawn simultaneously.

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LESSON IV.

Work Outside the Battery—Electro-Physical Action—Cataphoresis; Electro-Chemical Action—Electrolysis; Electro-Physico-Chemical Action—Catalysis.

HAVING in our previous lessons dealt with the common modes of generation of the continuous current when used in its application to medical purposes, as well as with conduction and with resistance, we are prepared to consider some of the phenomena dependent on the transformation of electrical energy into physical and chemical work.

This transformation takes place outside the battery, and is an accompaniment, as it is an evidence of resistance, and the work done—allowing for the loss referred to in Lesson I.—is the equivalent of electrical energy, expended in overcoming the resistance between positive and negative poles.

As examples of these properties of the continuous current, we propose to discuss (*a*) Cataphoresis, (*b*) Electrolysis, and (*c*) Catalysis, for it is upon the functions named that many important uses of the continuous current are dependent.

CATAPHORESIS (*a*).

In order that this function may be explained, it is necessary to refer briefly to the well-known purely physical phenomenon of *osmosis*. Speaking generally, the theory ot osmosis is, that when two fluids of varying density are separated from one another by a porous septum or animal membrane, diffusion takes place from the fluid of less through the septum to the fluid of greater density.

Fig. 18 illustrates a vessel (A) divided into two parts by a porous septum (B). Into one compartment we pour a fluid (C) of a certain density. In the other compartment we place an *equal bulk* of a fluid (D), whose density has been previously increased by the addition of a salt, such as sulphate of soda. After some time we note that the surface level of D rises, while that of C falls. There has been a transference of fluid from one compartment to the other in spite of the force opposed by gravity to such an alteration in level. But the process is extremely slow.

If, however, in C we place an electrode (E) connected with the positive pole of a battery, and in D an electrode (F) connected with the negative pole in the same battery, we shall find that the process of transference of fluid from C to D (other conditions being the same as in Fig. 18) will

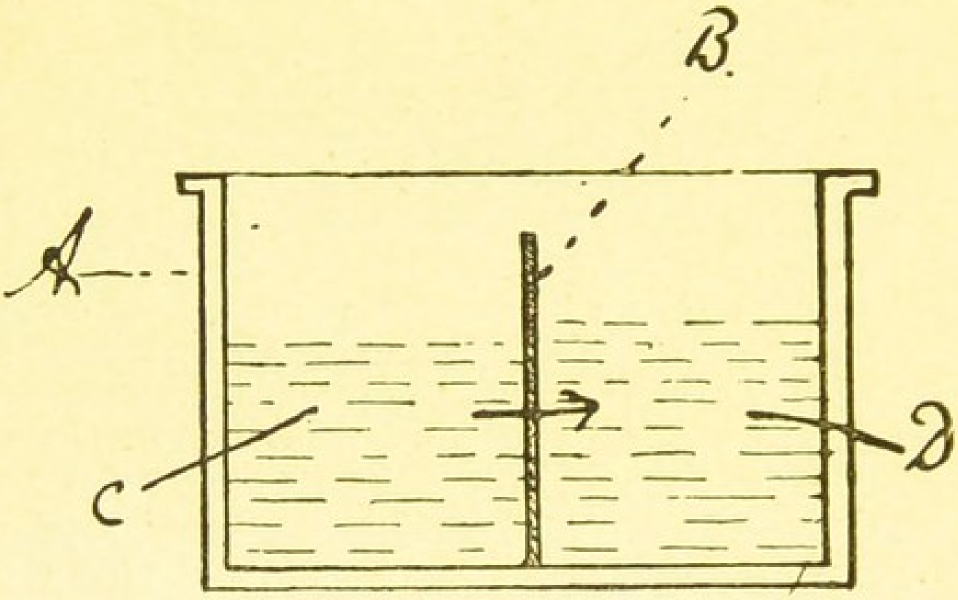


FIG. 18.

be much accelerated. In a given time the level of D will be very much higher when a current is passing from E to F than when osmosis, unaided by electricity, is the agent at work. But further than this, *independently of the respective densities of C and D*, there will be a transference of fluid from C to D when electrical energy from E to F is transformed into mechanical motion. There is an actual mechanical transference of fluids from C to D. This is what is meant by cataphoresis.

Further to illustrate this important process, upon which the method of *cataphoric medication*, to be hereafter referred to, is based, the fluid C may be replaced by a weak solution

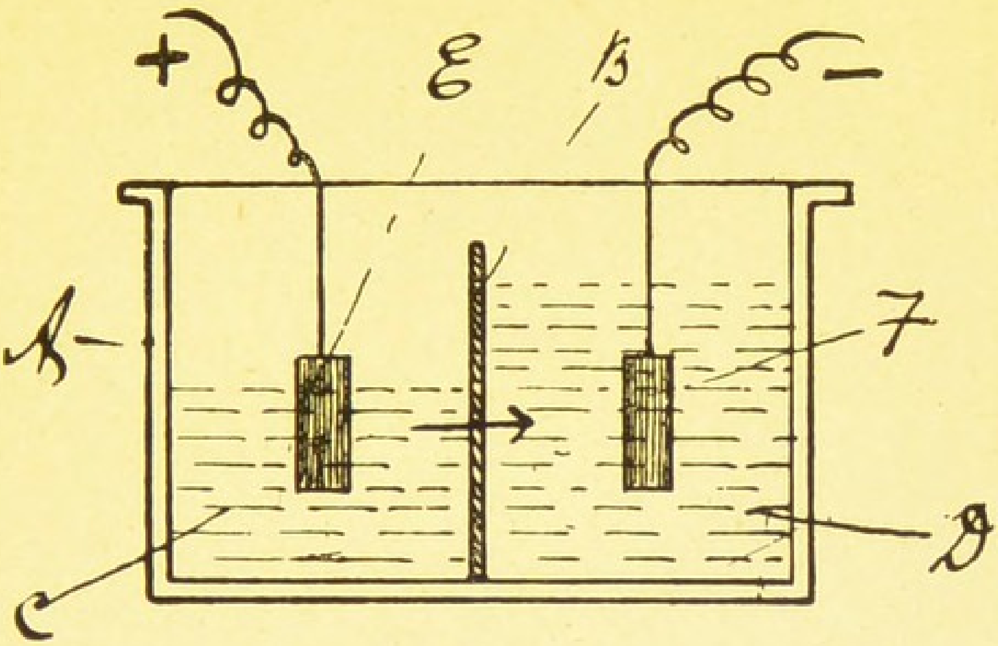


FIG. 19.

of iodine, and D by a weak solution of starch. The current passing from E (+) to F (—) through the fluids will carry with it through the septum (B) a portion of the solution of iodine. On that side of B nearest the negative pole (F) the ordinary blue starch-iodine reaction will be clearly seen, at first only in the region of the septum, but later in lines of colour from that to the electrode F.

ELECTROLYSIS (*b*).

This process is the reverse of that combination of chemical bodies which is induced by the passage of electricity (spark or otherwise). And in order that it may—from its vast importance in relation to many surgical and other procedures—be completely understood, as far as present knowledge will enable us to understand so marvellous a function, it will be necessary to remind our readers of certain phenomena dependent upon simple chemical action.

Chemical action is essentially a transmutation of energy. Power stored up (latent) in unoxydised bodies becomes active (kinetic) when conditions favourable to oxidation present themselves. During this process, the energy set free may manifest itself in heat, light, or electricity, or in some other forms of motion (sound, &c.).

A simple example of the development of heat by chemical combination is that afforded by the addition of sulphuric acid (oil of vitrol) to water. A thermometer placed in the mixture gives immediate evidence of rise of temperature. In this case the concentrated acid (H_2 So_4) enters into chemical union with certain molecules of water, becoming not merely diluted, but chemically united with it. This change is expressed by the symbols $H_2 \; So_4 + (H_2 \; O)_n = H \; So_4 \; (H_2 \; O)_n$.

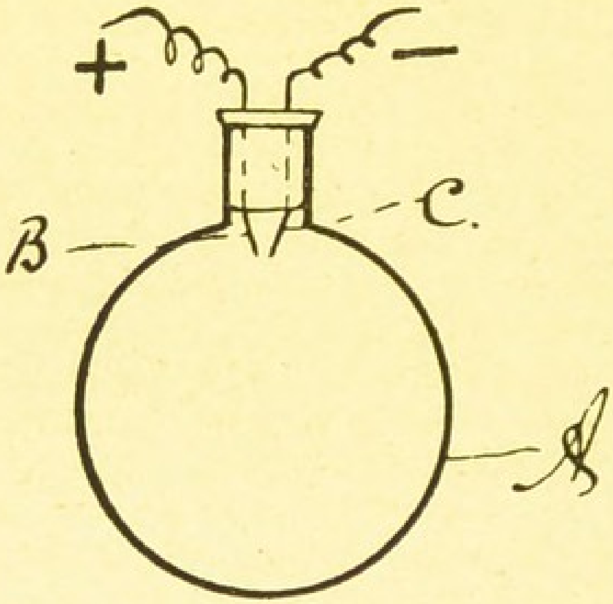


FIG. 20.

Again, a mixture of hydrogen and oxygen, in the proportion of two parts of the former gas to one of the latter, placed in a glass vessel, such as that shown in the subjoined figure, may be made to illustrate several facts closely related, though apparently dissimilar, to those discussed in the last paragraph.

A (Fig. 20) is a glass bottle of any convenient form sufficiently strong to withstand the strain of a mild explosion. Its neck is closed by a cork, perforated by wires B and C, connected respectively with the positive and negative poles of a coil battery. On completion of circuit, a spark passes between the points B and C, and simultaneously there is a loud explosive sound. This is caused by the union of the gases ($H_2 + O = H_2O$) ; that is to say, as the result of the passage of a spark through the gases, the mechanical mixture has been changed into a true chemical compound (water), and the main accompaniments of this action are found to be light, sound, heat, and diminution in volume. In this case the current has supplied the factor needed to complete the conditions requisite for the union of gases already mixed, though not united.

ELECTROLYSIS.

The experiments just referred to illustrate sufficiently for present purposes what is known as chemical synthesis, and will enable us to appreciate more easily the converse series of phenomena collectively known by the term *analysis*. In analysis we find the processes, so to speak, running backwards—disintegration of compound bodies, disappearance of heat, electricity and so forth.

Our special duty is to deal with that department of analysis which is connected with the transformation of electrical energy, and particularly of that form of electrical energy commonly known as continuous or voltaic, and which may conveniently be termed *electrolysis*.

By *electrolysis* we mean a breaking up of chemical compounds into their constituent elements by the agency of electricity, the process being accompanied by the loss of heat, and usually by change in the volume of the substance submitted to experiment.

The conditions requisite for the performance of electrolysis are :

(1) A fluid or semi-fluid conductor ;
(2) Conveniently placed electrodes ;
(3) A continuous current of sufficient electro-motive force to overcome the resistance interposed between the electrodes.

As the result of the passage of a continuous current through a suitable conductor, decomposition of the fluid takes place, acid bodies being set free at the positive pole, and alkaline bodies at the negative. The products of such action are termed "*ions*," those collecting at the + electrode *an-ions* those at the — electrode, *kat-ions*.

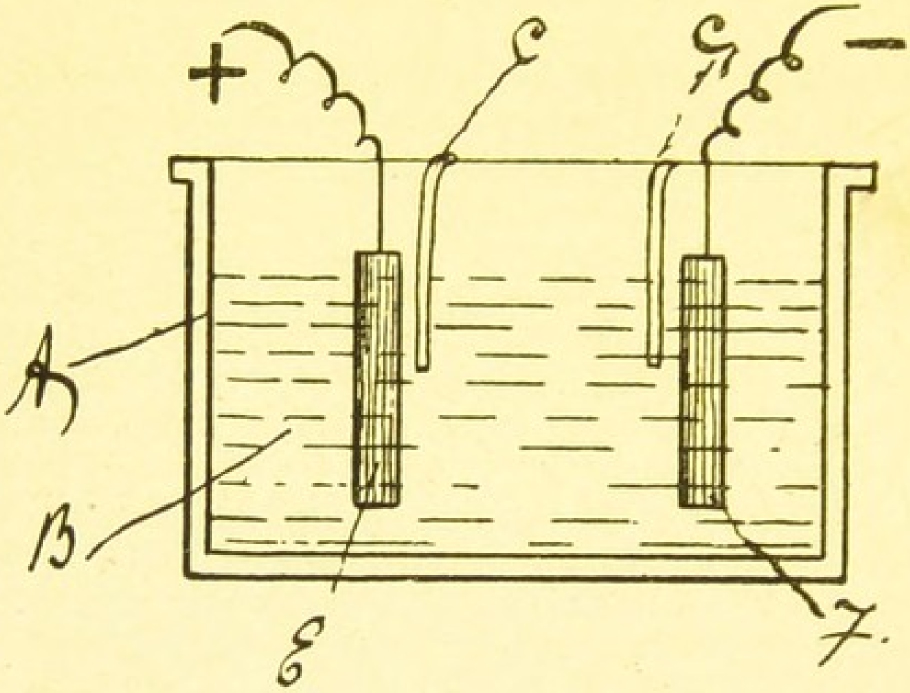


FIG 21.

Fig 21 shows a simple method of demonstrating these facts.

A is a vessel containing a solution of common salt B; C.C_1 are pieces of blue litmus paper suspended in the neighbourhood of positive pole (E) and negative pole (F) respectively; on passage of current from E to F through the fluid, C is reddened, while C_1 becomes more markedly blue, thus proving that acidity is produced in the region of the one, and the alkalinity in that of the other pole.

In Fig. 22 the same result may be shown even more clearly.

In this case B is coloured with a solution of litmus. The action of the current is to redden the fluid near E, and to deepen the blue tint in that near F.

The same principle applies to the process known as electro-plating.

Metal is deposited on bodies connected with the — pole, the acid separating, and being found at the + pole.

ELECTROLYSIS.

A further illustration of electrolysis, and one which will be of much service when we come to consider the applications of this function of the current to surgical purposes, is exhibited in the arrangement known as the voltameter.

Fig 23 gives a fair idea of this apparatus. A is an upright glass tube dilated into funnel or globular shape at its upper part; at its lower end it communicates by a cross-piece F with two smaller parallel tubes (D and D_1), each terminating at its upper end by a pointed nozzle (E and E_1) controlled by a glass stop-cock, and at its lower end by an arrangement which admits a wire (B and C), ending within the tube in a fine platinum electrode.

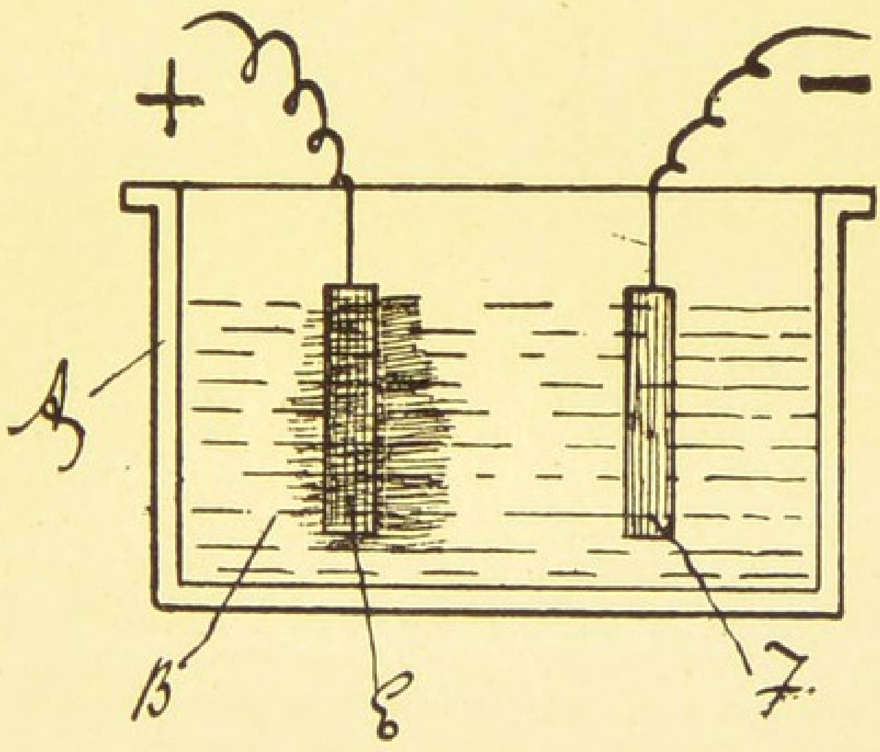


FIG 22.

A contains water slightly acidulated (to make it a better conductor), and the stop-cocks controlling E and E_1 being opened, the fluid is allowed to run, until it begins to pass out at E and E_1; the stop-cocks are now closed, and D and D_1 remain full of fluid. The liquid in A F has now

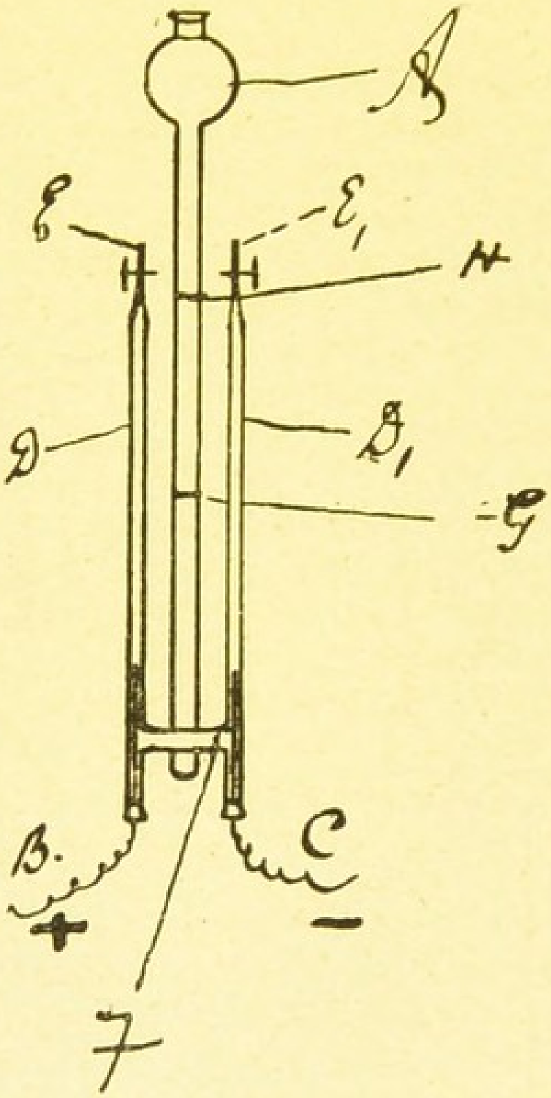


FIG. 23.

run down to G. If, however, a sufficiently strong current from B to C be slowly switched on, the level of G will rise until it reaches a point H. The side tube (E B) will now be half full of fluid, the upper space being occupied by oxygen gas, while E_1 C will contain only hydrogen gas.

The gases, hydrogen and oxygen constituting the water, originally contained in A F, have been separated from one another by the current, which has thus again demonstrated its function of electrolytic decomposition.

CATALYSIS.

We have to take into consideration under this heading a complicated series of phenomena, which can only vaguely be defined, but which are probably dependent upon several functions of the continous current.

Catalysis may be said to include both cataphoresis and electrolysis, together with certain other functions which go to produce the effects classified by Remak,* and the leading points in which may be selected as follows :—

(*a*) Dilatation of blood-vessels and lymphatics, with impulse to the circulation dependent on passage of an electric current.

(*b*) Increased power of absorption conferred upon the tissues.

(*c*) Promotion of osmosis, and following upon these two processes, increase of tissue bulk—especially in muscles. To these may be added the influence upon molecular exchange and nutrition effected by exciting or soothing the nerves directly, or indirectly through the parts which they supply; changes in molecular arrangement of vital structures and in their nutritive activity, due to the phenomena of electrolysis ; and finally, the consequences of the mechanical transference of fluids from one pole to the other.

We have thus in catalysis a connecting and overshadowing link between the cataphoric and electrolytic influences of the current, between the electro-physical and the electro-chemical processes described in the earlier portions of this lesson.

* Vol. vi., " Von Ziemssen's Electro-Therapeutics," by W. Erb, M.D., translated by Dr. de Watteville, page 129.

LESSON V.

Other Forms of Current—The Induction Coil—Interrupted Currents—Alternating Currents—Fallacy of the Term Faradic—Magneto Machines—Franklinic or Statical Electricity—Frictional machines—Influence Machines.

ELECTRIC currents generated as before described may have some of their properties so changed, and the relative value of the factors E.M.F. and C-s. so altered, that they become distinct forms of current, and are capable of producing entirely different effects upon the human body. Of these new forms we will now consider (*a*) interrupted

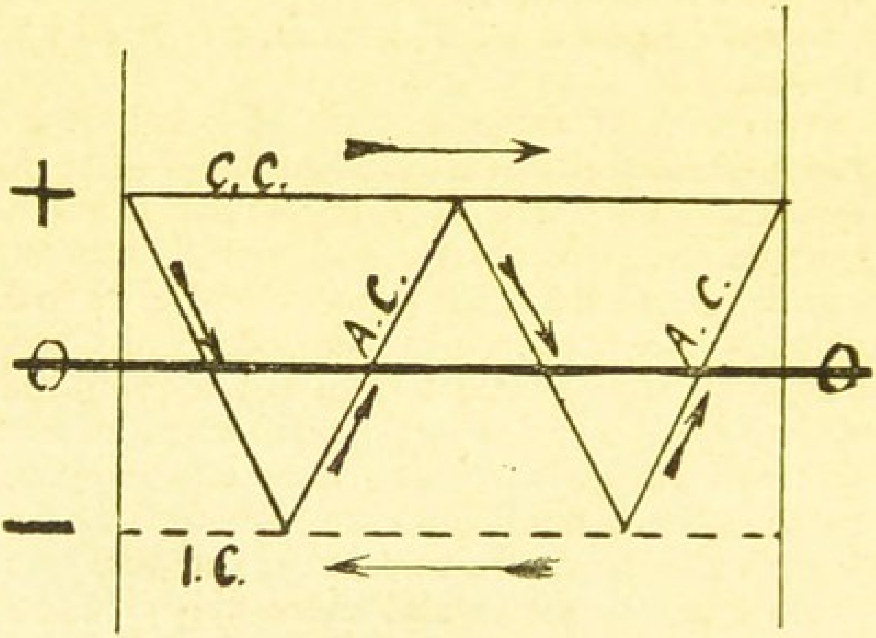


FIG. 24

currents and (*b*) alternating currents. The main characteristic of the interrupted current is that it flows always in the same direction, but is stopped and started again with more or less rapidity. Alternating currents, on the other hand, alternate in direction, and are always noticeable for their high E.M.F. and small C-s.

The above diagram (Fig. 24) illustrates in a general way the difference between the three forms of current, viz., continuous, interrupted and alternating. The straight, continuous line C C represents the continuous current flowing *steadily* in *one direction*. The straight, dotted line I C represents the interrupted current flowing *intermittently* at more or less regular intervals in *one direction*. The diagonal lines A C represent the alternating currents which rush across from positive to negative, and consequently *alternate in direction*.

The most common method of changing the continuous into either the interrupted or alternating current, or both, is by means of the induction coil.

The induction coil consists of the following essential parts, viz., a primary wire, a secondary wire, each twisted into a coil; an interrupting hammer or vibrating spring, sometimes called the contact breaker, and a soft iron core.

The primary wire receives the current direct from the battery, and contains within its electric circuit the interrupting hammer. The secondary wire is entirely separate from the primary wire and insulated from the electric circuit of the battery. The soft iron core is sometimes adjustable and capable of sliding in and out of the centre of the primary coil. Fig. 25 represents diagrammatically an induction coil.

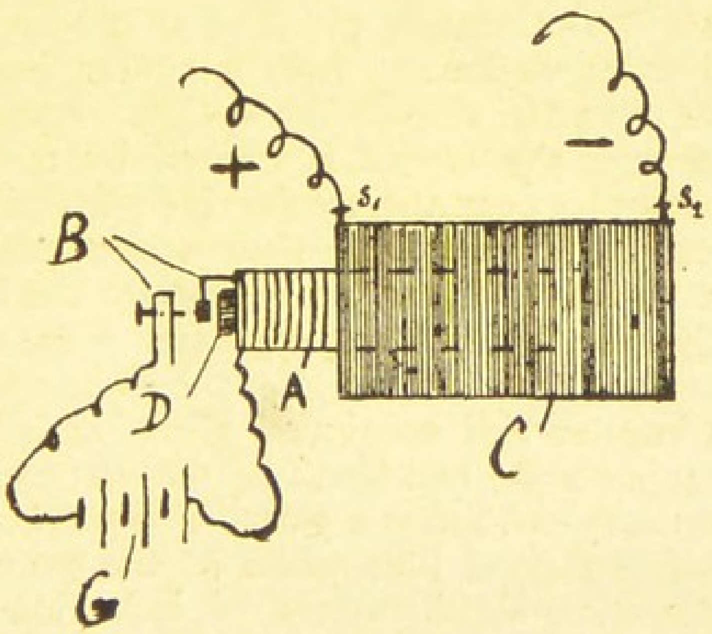


FIG 25

A is the primary coil, shown as a few turns of stout wire. B is the interrupting arrangement. C is the secondary coil, shown as many turns of fine wire, and pushed back a little in order to render A visible. D is the soft iron core, shown as a bundle of straight wires. G is the electric generator, shown as a battery of three cells. S_1 S_2 are the terminals from which the secondary alternating current may be conducted to the patient.

We will now trace the action of the different parts of an induction coil. The primary coil receives the current direct from the battery, but by reason of the interruptions in the circuit (caused by the interrupting hammer), and their effect upon the convolutions of wire, has set up within itself certain other currents, which are due to what is known as self-induction. The consequence is that the current obtained from the primary circuit of an induction coil is very different to that obtained from an equal length of wire of same size laid out straight and subject to the same rate of interruption.

The interrupting hammer or vibrating spring may be purely a mechanical contrivance for breaking and making again the electric circuit with suitable rapidity, but is more generally an electro-magnetic arrangement. A small electro-magnet is so placed that when the current is passed through its coils, a soft iron armature attached to a spring is drawn towards its poles, and away from a conducting pin fixed suitably near the other side of the spring. As soon as this happens, however, the circuit is broken by reason of the break of contact between the conducting pin and the spring, the poles of the magnet lose their magnetism, and the armature is forced back by the spring, till the latter again completes the circuit by making contact with the conducting pin.

Thus a regular and continued vibration is set up, involving the rapid make and break of the electric circuit of which the primary coil forms a part. The common electric trembling bell is a good illustration of the principle upon which the interrupting hammers of induction coils are worked. The primary coil and its soft iron core or an extension thereof often form the electro-magnet of the interrupting arrangement of induction coils, and it is so represented in Fig. 25.

The secondary coil generally consists of many turns of fine wire, and is so arranged that it and the primary can be moved relatively to one another. The wire of this coil is in no way electrically connected with the primary circuit. It depends upon induction for its electric properties, for when such a coil is placed near the primary coil in which interruptions are set up, currents *alternating* in direction are induced in it. The strength of these induced alternating currents is

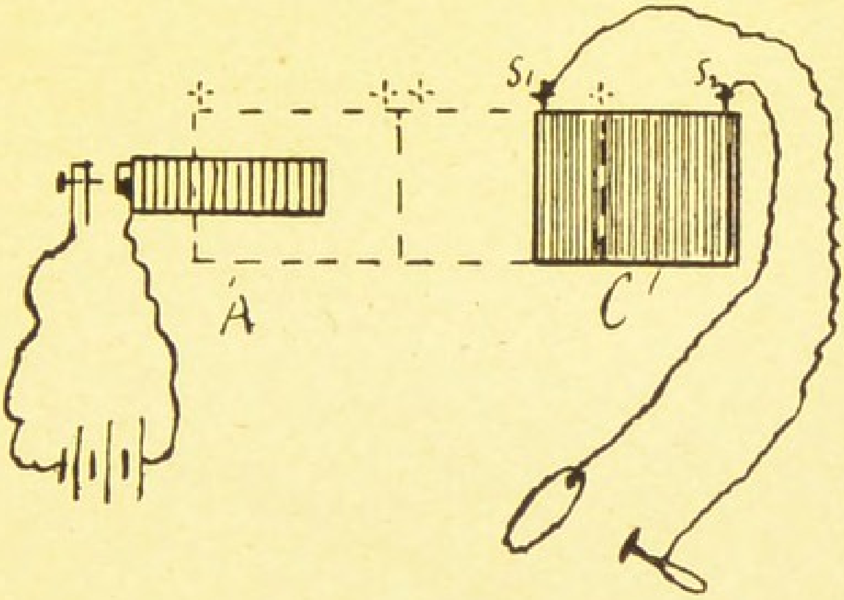


FIG. 26.

increased or diminished in accordance with the nearness of the secondary coil to the primary, being greatest when the secondary entirely contains the primary, and least when they are farthest away from each other.

The effect of the soft iron core is to increase the strength of the induced currents.

The most common methods of regulating the power of induction coils are as follows :—(*a*) Altering the number of battery cells used ; (*b*) altering the number of vibrations of the interruptor ; (*c*) altering the relative position of the two coils ; (*d*) altering the number of turns of the primary wire brought into circuit.

Striking evidence of the presence of induced currents may be noted by means of a simple experiment (see Fig. 26). As before, A is the primary coil, C the secondary. Attach two electrodes to terminals S_1 S_2, and let them be connected to some sensitive parts of the body—say the two hands (well moistened). Then start the coil with C in the position shown—*i.e.*, more than its own length away from A. Alternating currents will be distinctly felt by the subject holding the electrodes, and as C is in no way connected with any electric generator, it is manifest that whatever current comes from it can only be the result of induction. If, while everything else remains the same, C be steadily moved towards and over A, as shown by the dotted lines, the induced currents steadily increase as the distance between the two diminishes.

The test may be made still more delicate by substituting a telephone for the electrodes. Extremely small alternating

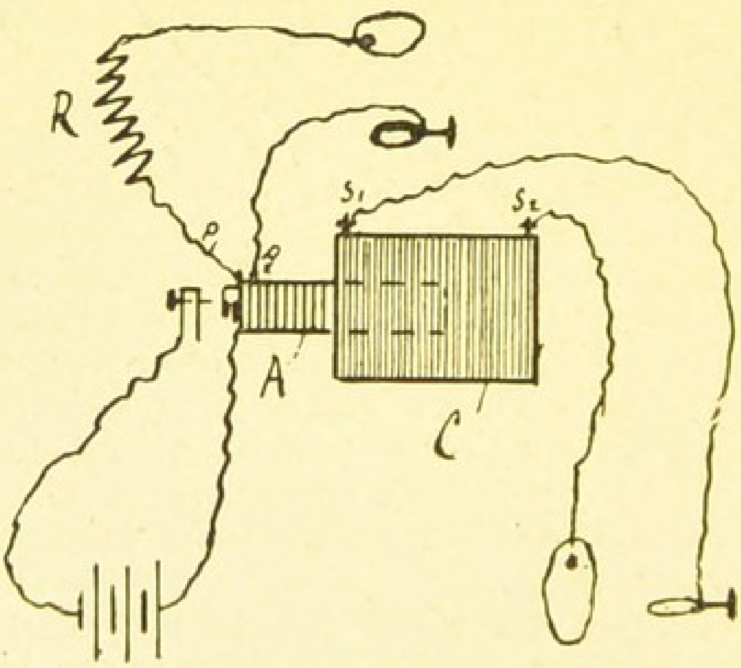


FIG. 27.

currents make a distinct humming noise in a telephone, and it will be found in this case that even when the secondary coil is some feet away from the primary a noise is heard in the telephone, thus showing the presence of induced currents.

All complete Medical induction coils should possess terminals from which the interrupted primary current may be drawn. Fig. 27 illustrates such an arrangement, and shows the two distinct circuits ready for work. The parts of the coil are as before, but in addition terminals P^1 P^2 allow of the attachment of electrodes to the primary circuit.

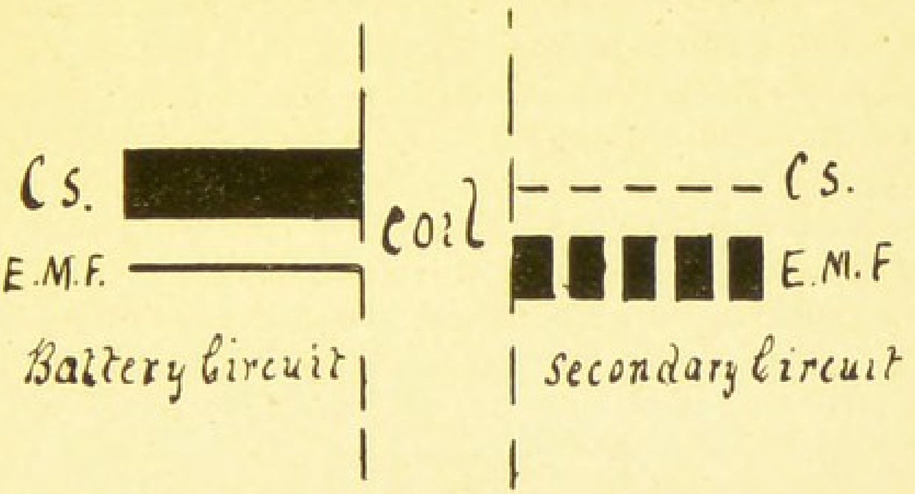


FIG. 28.

R is an adjustable resistance placed in series with the patient for the purpose of regulating the C-s administered.

The induction coil enables us to completely change the form of the continuous current supplied by a battery. Two or three cells are generally enough to work a medical coil. The current put in to the coil is therefore continuous in direction, and has low E.M.F., with comparatively large C-s; but as it leaves the secondary coil it is alternating in direction, and has high E.M.F., with very small C-s.

The diagram (Fig. 28) illustrates this. On the left side the factors C-s and E.M.F. are represented by two straight lines, the C-s being very broad as compared with the E.M.F., and this is the condition of things as the continuous current is put into the coil. On the right side the size of the lines is entirely changed, and they are also interrupted, thus representing the change, especially in the relative value of C-s and E.M.F., which is accomplished by the coil. It is manifest that this figure does not illustrate all the changes wrought by the coil, but it shows the most important of them. We will mention, as an example, the result obtained with a fair-sized medical coil at the Institute of Medical Electricity. The current was supplied to the primary coil at an E.M.F. of *seven volts* and C-s of *five hundred m.a.* passed; from the secondary coil we obtained *twelve m.a.* only at *two hundred and sixteen volts* E.M.F.

When it is remembered, as shown in Lesson III., that the factor of current-flow which overcomes R is the E.M.F., it is easy to see what an important change in the character of the current is brought about by use of the induction coil.

Before leaving this part of the subject, it is necessary to point out the incorrectness of using one term only to express the two forms of current obtainable from an induction coil. The terms Faradic and Interrupted, so commonly used for coil currents, are not sufficiently discriminating. The primary current is *interrupted*, and so is the secondary; but the latter is also *alternating*. These two forms of current are so different, and so differently affect the body (as we hope to show in a future lesson), that to apply the same term to both is *incorrect*, *confusing*, *and often distinctly mischievous*. Medical men should, therefore, be careful when giving directions for treatment by induction coil to state clearly which form of current they wish applied; and a Nurse on being directed by a Medical man "to *Faradise*" a patient, or to apply "the *Faradic* current," "the *Interrupted* current," or "the coil," should at once ask which current is really meant—whether the Interrupted Primary or the Alternating Secondary?

MAGNETO MACHINES.

These machines depend for their action upon the circumstance that when a coil of wire is revolved or otherwise made to move, so as to cut the lines of force within a magnetic field, currents of electricity are set up in that wire. They usually consist of a fairly powerful magnet of the horseshoe pattern, against the poles of which bobbins of fine wire are pivotted in such a way as to revolve rapidly when a handle is turned. The wires on these bobbins have currents of electricity generated in them in proportion to the number of lines of magnetic force which they cut as they revolve. The currents so generated are collected and conducted to the terminals of the machine. They are alternating as regards direction, and like the currents from the secondary of an induction coil, possess high E.M.F. and small C-s.

A few years ago Medical-magneto machines were very popular, owing to their handiness and cheapness, but for therapeutic purposes they have very little value, and are therefore seldom recommended now. The currents generated are usually jerky and unsteady, so that these machines may rather be reckoned as instruments of torture than as therapeutic aids.

FRANKLINIC OR STATICAL ELECTRICITY.

This form of electricity differs largely from those hitherto considered. It is chiefly to be noticed for its high potential and consequent power of overcoming resistance, while the C-s is very small. When a conductor is brought into contact with one of the poles of a frictional or influence machine in operation, it becomes electrically *charged—i.e.*, covered with electricity of high potential. This charge remains so long as the insulation is good enough to prevent its escape; but if the insulation be disturbed and broken down, the charge rushes away by any channel offered. If that channel be an air-space, the charge produces a spark in its passage. A charge of statical electricity is sometimes compared to the energy possessed by a wound-up or compressed spring, the energy being stored up so long as the spring is compressed, but being discharged in one sudden effort directly the spring is released.

The simplest method of generating statical electricity is shown by the following experiment. Take a rod of sealing wax or ebonite (making sure that the surface is clean and dry), and rub it briskly a few times against a piece of dry cloth or fur; a coat sleeve or cloth dress will do very well. Having placed on the table a few scraps of light paper, hold the rod in one hand, and present the freshly rubbed end to the paper scraps. They will at once spring up and attach themselves to the rod. The reason for this is, that the friction has left a charge of negative electricity upon the rod, while the paper scraps being connected to earth through the table, &c., possess a relatively positive charge. When these charges of opposite polarity are brought into proximity to

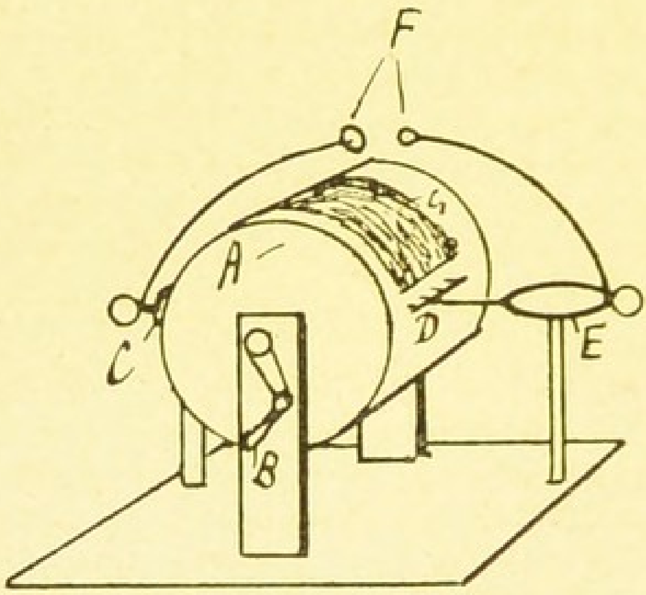


FIG. 29.

one another, their tendency to combine and their attraction for each other enable them to do a certain amount of work in the act of combination. The scraps of paper being very light are carried upwards against the force of gravity by electric attraction, and the first step in statical electricity—that of attraction—is demonstrated. The paper scraps do not adhere long to the rod, but soon fall back upon the table, because the act of combination of the two charges has brought about neutralization. There being no further electrical attraction, the paper scraps are no longer able to resist the force of gravity.

We thus see that electro-static charges of opposite polarity attract one another. In a very similar manner it may be shown that such charges having the same polarity repel one another, but we do not consider it pertinent to the object of these lessons to go further into the question.

FRICTIONAL MACHINES

may be briefly defined as convenient arrangements for multiplying the electrical action described in the experiment with the rubbed rod. One of the simplest forms is the cylinder electrical machine illustrated in Fig. 29. A is a cylinder of glass made to revolve by means of the handle, B ; C is a cushion covered with amalgam (having the silk flap C_1 attached), against which the glass rubs as it revolves ; D is a metal comb called the collector ; E is the prime conductor, insulated from the rest of the machine ; F points to sparking knobs, one attached to the prime conductor E (from which the + electricity is obtained), and the other to the rubber C (from which the — electricity is obtained).

The plate electrical machine is constructed with a circular plate or disc of glass, which takes the place of the glass cylinder in the first-named instrument ; but its action is practically the same.

INFLUENCE MACHINES.

These machines generate statical electricity more effectively and efficiently than the frictional machines. They depend upon induction or electric influence for their action, and are so constructed that a small initial charge, given from an external source, such as a rubbed rod, for instance, is speedily increased and multiplied many times in a few seconds.

Fig. 30 illustrates an influence-machine of the type known as the "Wimshurst."

A A are two glass plates, which, without touching one another, are made to revolve in opposite directions by the handle B. CC_1 are strips of thin metal foil, which act as both carriers and armatures. D D_1 are metal collecting combs. E is a metal conductor, carrying a collecting brush at each end, which latter comes in contact with each carrier as it rotates. F F_1 are the main conductors, which communicate the opposite charges of electricity to the sparking knobs G, or to other conductors, of which the human body may be one.

All machines generating statical electricity are liable to derangement by atmospheric disturbances. Any moisture which may settle upon the insulating parts of these machines is sure to cause leakage of the electricity generated, and this is often so serious a matter, that if the air of the room in which the machine is placed be at all damp the action fails entirely.

Influence machines are less liable to trouble on this account than frictional machines, but all of them require great care and attention to keep them dry and clean enough for satisfactory working.

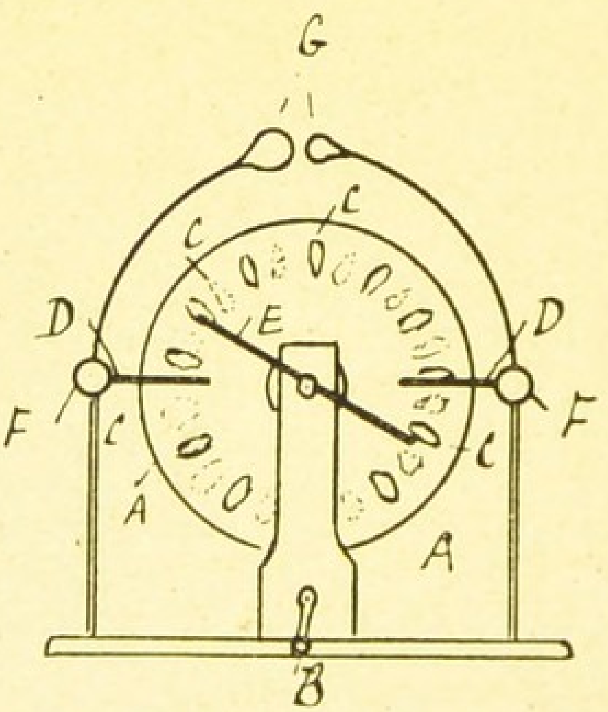


FIG. 30.

LESSON VI.

Need for Measurement—Measuring Instruments.

THAT accurate measurement of dosage is necessary is a truism recognised by Medical men, Nurses and patients alike, when drugs and old-fashioned medicines are concerned; but unfortunately electricity is by many regarded as an exception, and the need for its measurement for Medical purposes entirely ignored.

A little consideration, however, will show the need for the accurate measurement of doses of electricity. A continuous current possesses the property of producing various chemical changes in the tissues and fluids of the body (as shown in Lesson IV.), and the extent of these changes depends upon the C-s employed and the length of time during which it passes. If, then, we proceed to pass an unknown C-s for an indefinite time, it is manifest that we may easily either produce far greater changes in the body, or part of it under treatment, than we intend, and so do harm instead of good, or we may produce changes so slight as to be entirely valueless.

Dosage of electricity must be defined in terms which represent definite and distinct measurements expressed in recognised units. The factors of a dose of electricity are C-s and Time. The methods of measuring the latter it is needless to refer to; suffice it to say that the unit employed is the minute. The measurement of the former is not quite so easy, and we will now proceed to give a short description of the methods employed.

The instruments most commonly used to measure C-s are called galvanometers, or when suitably graduated, am-meters, ampère-meters or milliampère-meters. They depend for their action upon the magnetic influence of the electric current. The fundamental principle is easily shown by what is known as Oerstedt's experiment, illustrated in Fig 31.

A magnetic needle NS is pivoted on the stand A, and a single copper or other conducting wire BC is held just above and parallel to it. If a current of electricity from two or three cells be passed through BC, the needle NS will deflect and tend to set itself at right angles to its previous position. It will remain more or less deflected, according to the strength of the current passing, so long as the current continues to pass in the same direction.

If, instead of the single wire of the above experiment a coil of wire be used, and so arranged that the needle be pivoted or suspended in the centre of that coil, the action of the current upon the needle is much stronger. By using

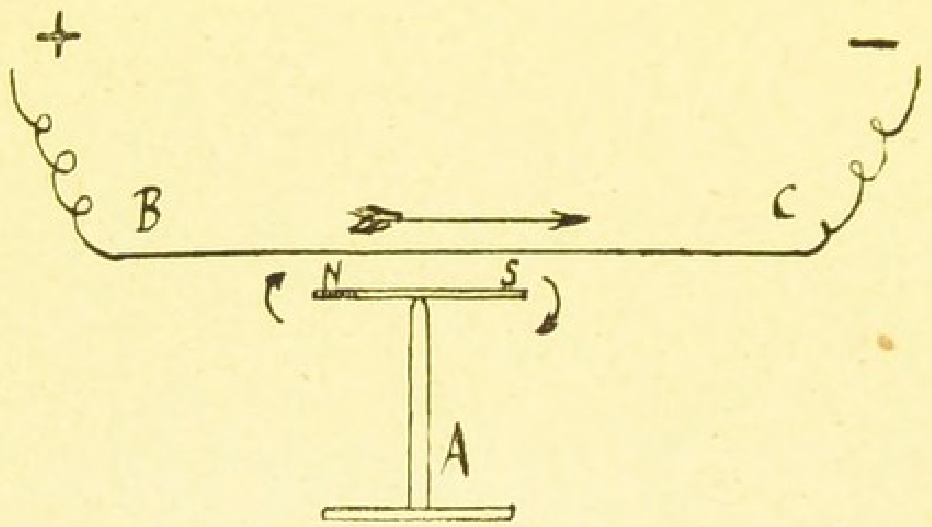


FIG 31.

many turns of fine wire, the effect of the current is multiplied many times, so that a weak current may produce a large deflection of the needle.

The magnetism of the earth has, of course, to be taken into account in any instrument which depends upon electro-magnetic action, and many forms of galvanometer have been constructed to reduce this difficulty to a minimum. One of the best of these is known as the astatic galvanometer, in which two magnetic needles of equal strength and size are fixed together, one above the other, in reversed positions, as shown in Fig. 32.

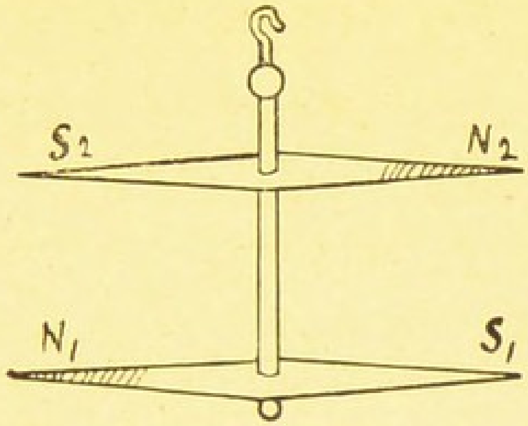


FIG. 32.

The force which urges N_1 S_1 to set itself in the magnetic meridian is exactly counterbalanced by the force which acts upon $S_2 N_2$. This astatic pair of needles will therefore remain in any position in which it is placed, and is independent of the earth's magnetism.

Any galvanometer will not do to measure the small currents, which are, for the most part, used in Medical work, for the simple reason that the coils employed have to be wound in accordance with the quantity of C-s it is desired to measure. A galvanometer, for instance, constructed to measure the strong currents used in electric light and power work would not deflect at all with the few milliampères which are required in Medical work, and a delicate galvanometer suited to the measuring of small currents, would be seriously injured if a current from a light-circuit were to pass through it.

Galvanometers for Medical work should be graduated in milliampères (the milliampère being the one-thousandth part of the ampère, which is the *unit of current strength* as shown in Lesson III.), and it is very necessary that attention be paid to this. Most galvanometers sent out by medical instrument makers are simply current indicators and not current measurers. The divisions of the scale marked on the face of the instrument are often equal throughout, and, therefore, do not mark proportional increments of the current which passes through the instrument, while the value of each division is altogether an unknown quantity.

Unless a galvanometer be graduated in *m.a.*, or has been "calibrated" so that the value of its deflections be known in terms of *m.a.*, it is of very little service in Medical work and should never be employed by those who value accuracy.

It is not difficult, however, to obtain at a reasonable cost galvanometers graduated in *m.a.*; nor is it difficult to calibrate one not so graduated so that the value of its deflections may be known. All that is required is the loan

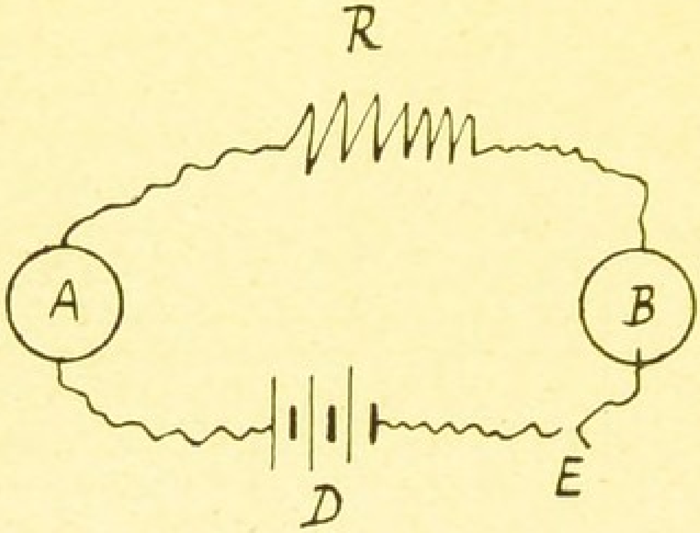


FIG. 33.

of a milliampère-meter for a few minutes, the galvanometer to be calibrated, a small battery, an adjustable resistance (such as a few coils of wire or a water rheostat), and a sheet of squared paper.

Fig. 33 shows how the instruments should be arranged for the purpose. A is the standard milliampère-metre, B is the galvanometer to be calibrated, R is the adjustable resistance, D is the battery, and E the switch.

Having arranged the connections as shown above, make the resistance R sufficiently high to allow such a C-s to pass, when the circuit is completed, as will indicate 1 *m.a.* on the standard A, then with the same C-s passing read the deflection of B. Reduce R till A records, say, 4 *m.a.*, and simultaneously read the deflection of B. Repeat observations with increasing C-s at reasonable intervals till the maximum deflection of one or both instruments is obtained. These observations should be recorded carefully, and then plotted upon the squared paper in the manner shown in Fig 34. Let us suppose that we have obtained the following readings :—

A.			B.	
Milliampères	1	...	Divisions	1·5
"	4	...	"	4·5
"	10	...	"	10·0
"	15	...	"	13·5
"	20	...	"	17·0
"	25	...	"	19·5

Taking the values of A (in *m.a.*) and of B (in divisions)

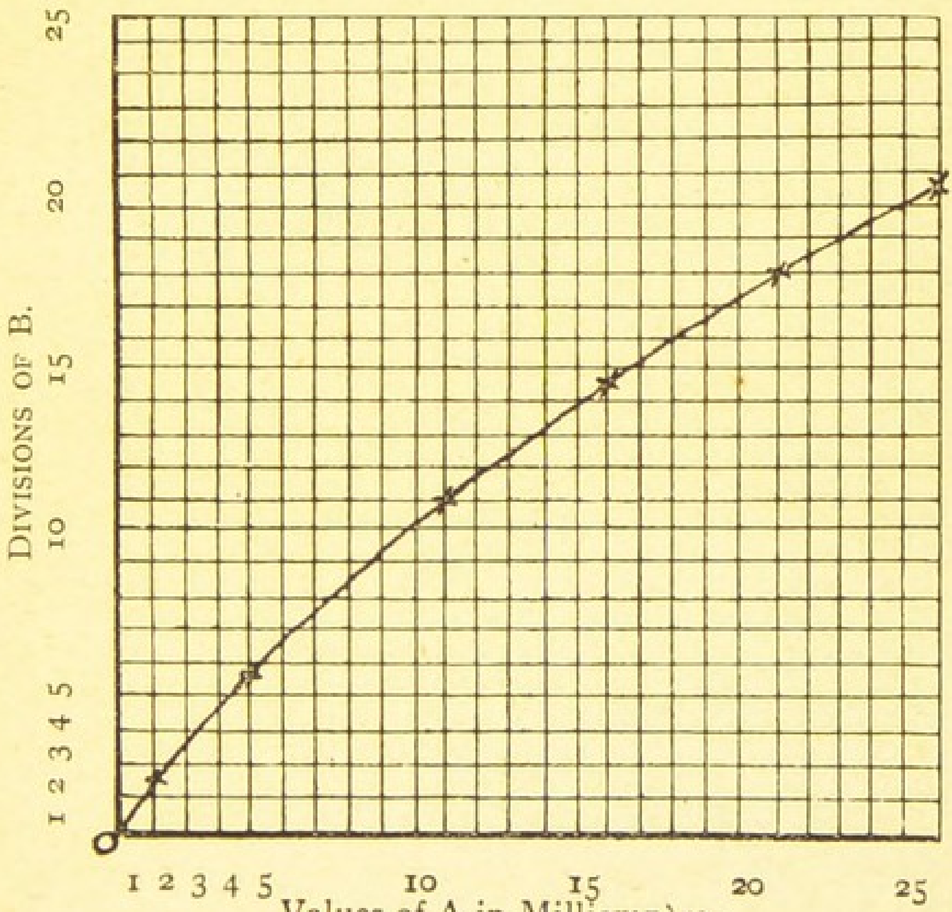


FIG. 34.

we then plot the curve, and by its use are able to see the value in *m.a.* of any deflection upon the galvanometer B.

For instance, 7 divisions = 6·5 *m.a.*, 12 divisions = nearly 13 *m.a.*, 18 divisions = 22 *m.a.*, and so on.

As long as we have this curve to refer to, B is practically as useful to us as A would be, because though its scale is not marked off in *m.a.*, yet we know the value of its divisions in terms of *m.a.*

The voltameter is another form of instrument for measuring C-s and depends upon the electrolytic action of the current (see Lesson IV.), the amount of gas set free in a certain time being a measure of the C-s employed. These instruments, however, are not of practical use in medical work.

Galvanometers of very high resistance may be used to measure the E.M.F., or rather the potential difference between any two parts of an electric circuit. Such galvanometers are generally graduated in volts, and are called voltmeters.

In Medical work the voltmeter is very little used, and is only necessary to test the condition of the battery. A milliampère-meter, however, should always be in circuit with the patient during electrical applications, as *by this means only is it possible to properly measure the dose given.*

LESSON VII.

Rheophores—Covered Electrodes for Medical Purposes; Plate and Handle; Standard Sizes and Areas; Bare Electrodes for Surgical Purposes.

WE have now considered the generation and transformation of electricity, and its control and measurement, so that before proceeding to describe its effects upon the body, and the various methods of application, we have only to deal with the conducting media called electrodes, which are used to communicate the electricity to the body by direct contact, and the wires or other conductors, called rheophores, which connect them to the battery.

The rheophores may be simple wires of conducting metal, but are more often stranded cord or braid, having fine copper wire closely woven in with the cotton so as to be very flexible. All rheophores should be *well insulated*, for otherwise they may cause shocks to be received by the patient through accidental contact or they may short-circuit the battery through accidentally touching one another.

Electrodes vary much in size, shape and material, according to the form of application they are required for. We will consider them in two classes, viz.:—(A) Covered electrodes for Medical purposes; (B) Bare electrodes for Surgical purposes.

(A) The general requirements for these are:—(1) Good conductivity; (2) Firm pliability, so as to make complete surface contact with the whole area of the skin covered; (3) Compactness, so as not to occupy unnecessary space; (4) Good insulation for such part as has to be handled by the operator; and (5) general handiness and cleanliness.

(1) Any good conducting metal will fulfil this condition, but it is necessary to remember that, except under very special circumstances (to be hereafter referred to) the

metal must not be allowed to come in direct contact with the skin of the patient. Electrodes are, therefore, covered with some soft material, such as flannel or chamois leather, by way of padding. These covers, when dry, are very bad conductors; but when moistened with water, or better still with salt and water, become good conductors.

(2) This condition is, perhaps, best illustrated by reference to the human hand, which is so pliable that it can easily form itself to the shape of any surface it is required to rest upon, while at the same time it is firm enough to retain its form under pressure. Of course, no mechanical electrode can equal the human hand in this respect, but it is easy to see that the condition may be fairly well fulfilled without the use of any elaborate or costly construction. Thick slabs of metal are too rigid, and thin strips of metal foil too flexible.

(3) By compactness we mean that the parts of the electrode which form the handle, or the means of attachment to the body of the patient, as the case may be, and the terminal for connection with the rheophore shall be as small and unobstrusive as are compatible with utility. This is specially necessary with electrodes which have to be passed beneath the clothing of a patient.

(4) The handle, of whatever shape and material it may be, must be well insulated, so that the operator may not receive any of the current intended for the patient. When the insulation of a handle becomes damaged, so as to promote electrical leakage, it should not be used further till it is repaired.

(5) By general handiness we mean that the shape of the electrode and its attachments should be such as is best suited to the particular work it has to do. Clumsy instruments are never conducive to efficient working.

Cleanliness is very important. All electrodes should be so constructed that *each* and *every part thereof* may be *easily* and *quickly cleaned*, and if necessary disinfected. Pads and covers are best made of inexpensive material, which may be frequently renewed at nominal cost. If they be elaborate and costly there is much risk of their being allowed to become dirty and even infectious. It must never be forgotten that the frequent contact with the skin of different patients which most electrodes make, renders it absolutely necessary that the contact surface should be at all times clean beyond suspicion.

This class of electrodes may be further subdivided into plate electrodes and handle electrodes.

Plate electrodes are those which can be most readily attached to the body of the patient or upon which the body may rest. They are of comparatively large area and of many shapes. We will illustrate a few.

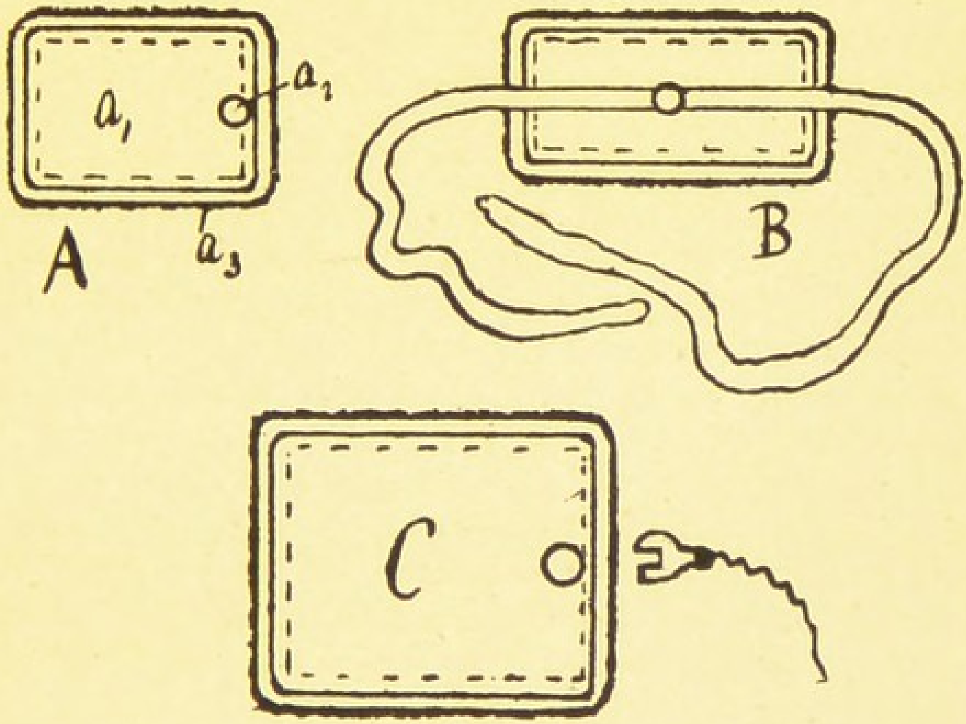


FIG. 34.

Fig. 34 shows three plate electrodes drawn to quarter scale. A is a convenient shaped plate for attachment to various parts of the body (such as the lumbar region of the spine or the abdomen); a_1 is the metal plate, a_2 the terminal for the rheophore attachment, and a_3 is the flannel pad. B is a neck plate. C is a foot plate showing a rheophore ready for attachment. B is shown with a tape band or strap for fastening round the neck. A might be also so furnished, but we prefer to have the tape or band separate, as it is likely to get damp and so prove unpleasant to the patient, and it is also more cleanly.

We have found the most convenient metal for plate electrodes to be *block tin*, as it is easily bent to any required shape, and does not readily crack when straightened out again. It can also be cut with an ordinary pair of scissors to any special shape that may be desired.

Another form of plate electrode which we have found very convenient to tie upon the limbs is made with broad metal braid—theatrical costumier's braid answers very well —which is cut to the desired length and padded with two or three thicknesses of flannel. A flat terminal screw let into the back completes the arrangement, which may or may not have tapes for tieing on attached.

Handle electrodes are those which are supplied with an insulated and insulating handle to facilitate use by the operator, especially when stroking or other labile applications have to be carried out. They are generally circular

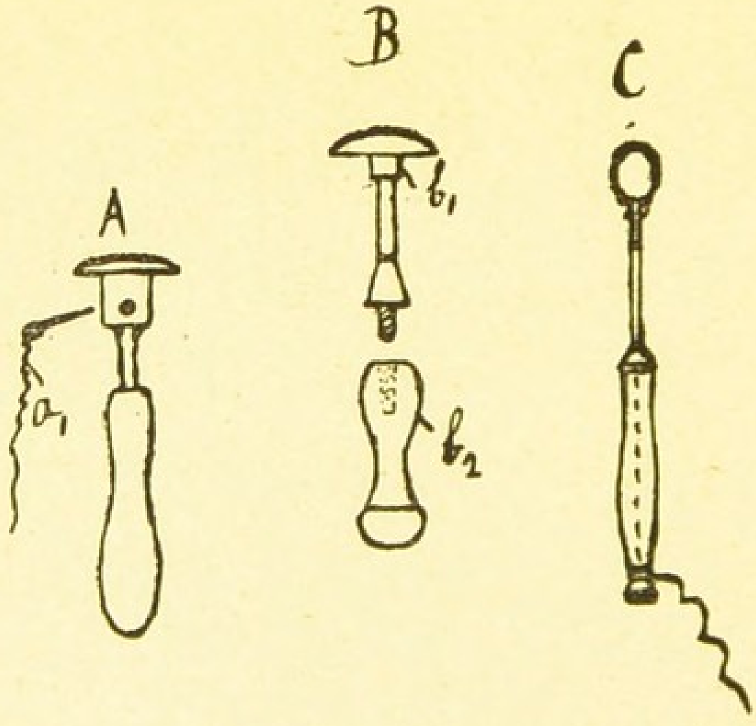


FIG. 35.

in shape, and are made of some good conducting material, such as copper, tin, brass or carbon, with handles of wood, vulcanite, porcelain, or glass. The portion which comes in contact with the skin of the patient—*i.e.*, the electrode proper—is generally covered with some padding material, similar to that used with the plate electrodes above referred to.

Fig. 35 illustrates some forms of handle electrode. A is a solid electrode, with pin-hole attachment for the rheophore a_1. B is an electrode with interchangeable handle, b_1

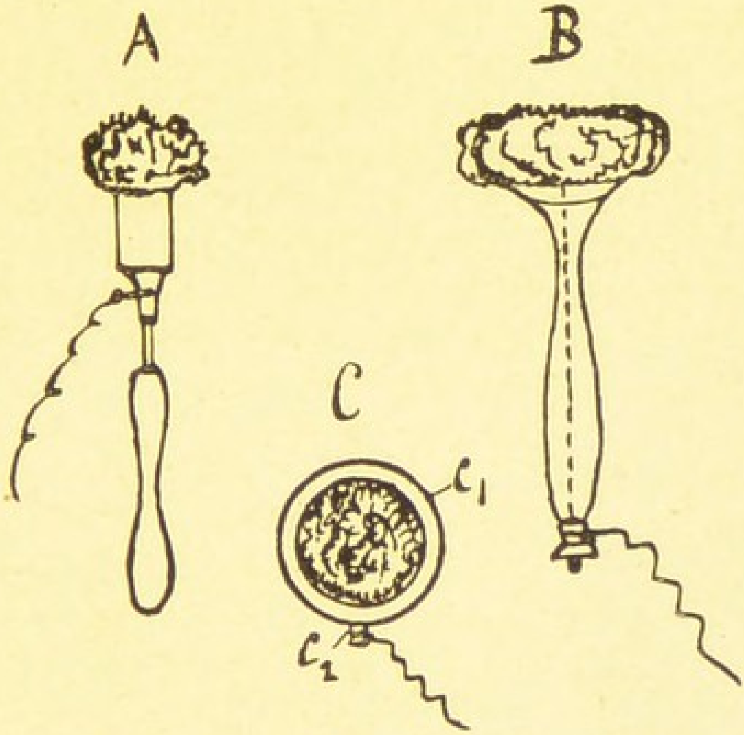


FIG. 36.

being the metal electrode, covered with flannel or other padding, and having a screw attachment to fit into the handle b_2, the screw socket of which is shown by dotted lines. A hooked rheophore—such as that shown in Fig. 34.—can be fixed in between b_1 and b_2, as they are screwed together. C is a fine electrode with round head, and having its rheophore connection at the extreme end of the handle.

Some handle electrodes have sponges attached in lieu of the padding, and these form a very useful surface for contact with the skin in some cases on account of their soft and pliable nature. The common form of sponge-holder is, however, very objectionable, on account of the insufficient hold it has upon the sponge when used for labile applications.

Fig. 36 shows three forms of sponge-holder. A is the common form, which, as stated above, we cannot recommend. B is a very useful form, the sponge being held in position by a metal rod, which passes right through the handle, along the dotted line shown, and which also acts as a conductor for the electricity. C is a cup sponge-holder (Dr. Steavenson's form). The vulcanite cup c_1, whose edge only is shown in the drawing, is shallow, so as to be easily passed beneath a patient's clothes. The sponge is screwed on to the centre of the cup, and is connected to the rheophore attachment c_2.

It is advisable to have all electrodes which have to be used with a handle made with a screw attachment, and all handles of whatever size and shape with a screw-socket, so that any handle may be used with any electrode, and *vice-versa*. As it is desirable to be as accurate as possible in all Medical work, and as the size of the electrodes, or rather their surface area which comes in contact with the skin, has much to do with the quantity of C-s which will pass through a patient, it is advisable to have all electrodes of known surface area, and also in regular progressive sizes. Erb recommends the following sizes and areas :—

Fine, circular, with a diameter of	0·5	centimetre
Small ,, ,, ,,	2·0	,,
Medium, square, with a surface of	20 sq.	,,
Large, rectangular ,,	50	,,
Very large ,, ,,	100 or more	

The medium and large electrodes may often with advantage be circular in shape, in which case their diameters will be 2·5 and 4 centimetres respectively.

This arrangement of size and area seems reasonable and convenient, and we think it might be generally adopted with advantage ; but it by no means covers the whole ground of what is required for external application. Modifications are often required for special cases, and the ingenuity of the operator must be trusted to supply these when needed ; but the standard electrodes above referred to will be found sufficient for almost all ordinary external treatments.

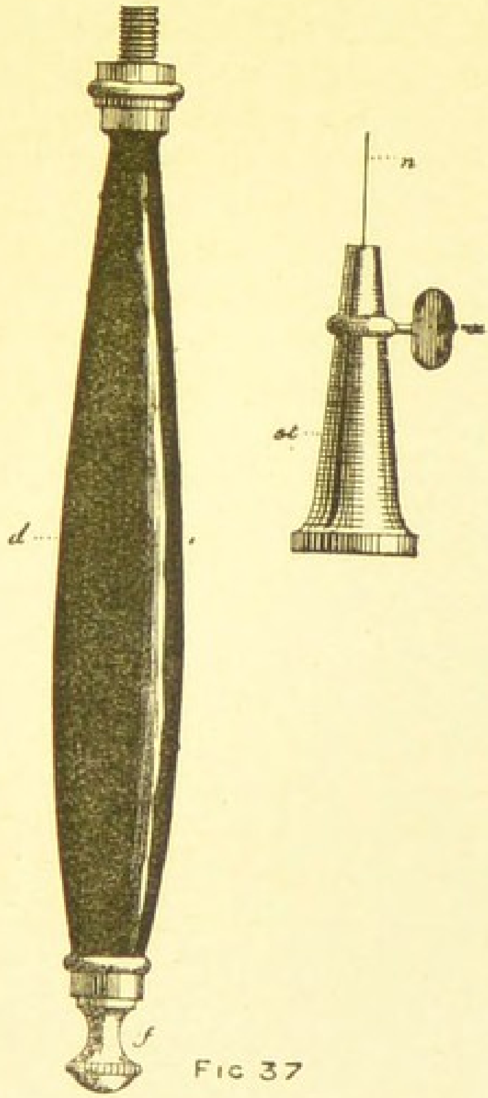


FIG 37

All rectangular electrodes should have their corners rounded off, and great care should be exercised with the pad covers so that they extend well beyond the edge of the metal. If the metal comes in direct contact with the skin, electro-chemical action is set up at the point of contact and a scar results.

Bare or surgical electrodes may be broadly defined as electrodes whose application brings the metal into direct contact with the skin or other tissue which it is desired to influence, and which are, therefore, *bare* of any intermediary. They may be classified into (*a*) cutting and (*b*) non-cutting instruments, and their number is legion. A detailed description of each of the developments of the bare electrode would carry us far beyond the scope of these lessons; and though it may be as well to mention in Class *a* single and multiple needles (straight and curved), knife and trocar electrodes, wire electrodes and the galvano-cautère; and, in Class *b*, rectal, œsophageal, vesical (or urethral), eustachian and uterine electrodes, we intend to illustrate only in—

a.—(1) The straight needle electrode (Fig. 37).
(2) The nœvipunct (Fig. 38).
b.—(3) An œsophageal bougie electrode (Fig. 39).

a.—(1) This consists of a straight platinum needle (*n*), an inch or more in length, and as thick as an ordinary sewing needle. Its point is fairly fine, and its base sufficiently stout to give it the requisite stiffness (platinum bends easily). This, when in use, is fixed into a metal stem (*st*) by a small side-screw (*x*), and the stem in turn emerges from a hollow vulcanite or ivory holder (*d*), through which passes a wire connected with a terminal screw (*f*), which may thus easily be fixed to the end of a rheophore.

a.—(2) The nœvipunct is an instrument designed by Dr. Harries,* which is intended to combine the advantages of multiple loose needles without the disadvantages inseparable from the difficulty of retaining the latter in proper position, and of rightly estimating the depth to which the needles are inserted into the tissues to be operated on. It consists of a perforated metal plate (*p*), with a strong central stem (*c*), within which slides a smaller stem (*d*) regulated by a screw (*e*), to which is fastened a perforated insulating screen (*f*) of vulcanite, glass or other material. The screen (*f*) is movable along the calibrated stem (*c*), which is in turn fixed to a hollow insulating handle (*g*). The screen (*f*)

* This design has been well carried out by Messrs. Coxeter and Son, of Grafton Street.

may then be fixed by its screw (*e*) at any point along the groove. Through the plate (*p*) pass a number of movable, straight, platinum electrolysis needles of equal length (*n*), and capable of being separately fixed to the plate by the fine screws (*xx*). When not in use the points of these needles

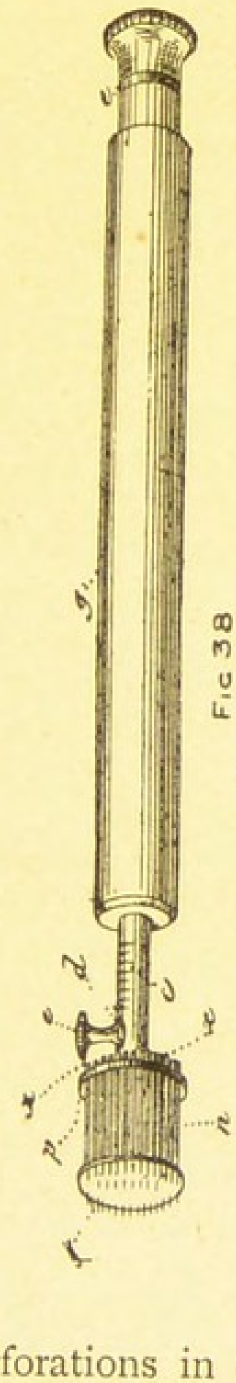


Fig 38

HARRIES' ELECTRIC NŒVIPUNCT.

reach as far as the perforations in the insulating screen (*f*). By moving the screw (*e*) the screen (*f*) is advanced or retracted, the needle points being correspondingly exposed or withdrawn in relation to the distal surface of the screen. The calibration of the groove enables us to determine with accuracy the length of the needle exposed beyond the screen, and thus to make certain of the depth to which it is possible to pass the instrument, while the fine screws (*xx*) enable us to use just as many needles as necessary and to arrange them as may be advisable. Through the handle (*g*) passes a wire connected at one end to the grooved stem (*c*), and at the other to a screw (*e*) for connection with a rheophore.

b.—(3) The œsophageal bougie electrode may be considered as representative of its class. It consists usually of a gum elastic tube (*x*) of any desirable size, terminating at its distal end in a brightly-polished, rounded, elongated, or olive-shaped, metal knob (*k*). At its approximate end is an arrangement (*r*) by which the copper wire passing through it may be easily placed in connection with a rheophore. Figure 39 clearly illustrates this and renders further description unnecessary.

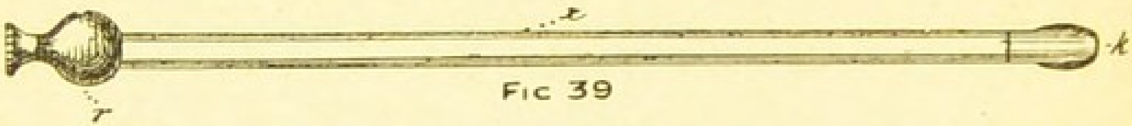


FIG 39

LESSON VIII.

Physiological Action (*a*) of Continuous Current; (*b*) of Interrupted Current (*c*) of Alternating Current.

(*a*) OF CONTINUOUS CURRENT.

IN Lesson IV. some of the physical and chemical functions of the continuous current were described under the headings of Cataphoresis, Electrolysis, and Catalysis. We have now to carry our investigations a little further than the purely experimental stage, and note the results of the application of some of these powers to the problems presented by living tissues. Most of these results are capable of being explained on ordinary scientific grounds. Others can scarcely be said to be satisfactorily accounted for even theoretically.

It will be convenient in the first place to mention very briefly the phenomena of catalysis, for it is these that chiefly concern us in the use of covered electrodes.

The first visible consequence of the application of a sufficient continuous current to the human skin is a reflex jerk, which is not repeated until or unless the current is varied in strength, or is suddenly broken. Very soon the part in contact with the electrode becomes reddened (physiologically congested), and this is due, probably, to the two factors of vessel-nerve paralysis and stimulation of the blood-stream. Thus the blood-current becomes more rapid, and the small vessels through which it passes being no longer controlled by their motor (or contractile) nerves, the current area is at the same time increased. The larger proportion of blood thus supplied to the part influenced heightens its tint, and at the same time allows the ordinary consequences of improved blood-supply to show themselves. The part feels warm (sometimes unpleasantly so), nutrition is improved, and absorption and exchange of tissue are accelerated.

In addition to this, the researches of Dr. Stone and others have shown that passage of a continuous current converts the portion of the body traversed into a secondary battery, or, in other words, sets up a condition of polarization—*i.e.*, a current opposite in direction to that which is being used is initiated in the body, and goes to reduce the current strength capable of being passed from the outside with a given electromotive-force. This point will require further consideration when we come to discuss skin-resistance.

As accompaniments of these functions there is general stimulation of tissues (muscle, nerve, &c.) in the neighbourhood, and not infrequently there is alleviation of pain.

The experiment illustrated in Fig. 19 has already shown that there is an actual mechanical transference of fluids, from the anode to the cathode in cataphoresis under suitable circumstances, and the experiment known as Porret's has proved to demonstration the fact that semi-fluids actually collect at the cathode.

German observers have made use of this cataphoric function, to show the possibility of passing certain solutions through the skin with the aid of the continuous current. A few attempts have been made in this country, also, to take advantage of it in the administration of drugs. But most of these have been half-hearted, and some experimenters have hoped to be successful when even the elementary conditions have been disregarded. We have, however, in several cases succeeded in bringing this power of the current to our aid, and by chemical and other tests have proved beyond doubt that in cataphoresis, properly applied, we have a therapeutic aid of much potency, the possibilities of which are probably illimitable. On a later page we shall give indications as to cases suitable for, and the methods of applying, cataphoric medication. At present we are content to refer our readers for further information on the subject to a letter by Dr. Harries in the *Medical Press* of December 11th, 1889, and a paper in *The Lancet* of October 25th, 1890.

The electrolytic function (see page 89), will require somewhat full treatment when we come to its Surgical applications. Until then we postpone further mention of it, and of dilatation and other curious effects of the application of the bare electrode.

(*b*) THE INTERRUPTED PRIMARY.

The physiological action of the interrupted primary current will not demand any lengthened discussion. It is sufficient to state that it holds a place—as regards function—between the continuous and the alternating (or secondary) currents. With currents of great strength, it may be that electrolysis is possible, both with the interrupted primary and the secondary current, but with the C-*s* ordinarily employed in Medical work, we may safely leave this power out of consideration. The catalytic action of the continuous current is to some extent probably present, for we soon observe congestion in the part to which application is made. This is due partly, no doubt, to local paralysis of the vaso-motor nerves, but chiefly to stimulation of the blood-stream in the interpolar regions.

Generally we may look upon the interrupted primary as a local stimulant, though, when the breaks are rapid, it is often of service in relieving pain.

(*c*) THE SECONDARY, OR ALTERNATING, OR COIL CURRENT.

Usually the coil current is looked upon as having its chief use in the regulation of function, whether of muscle or of nerve.

On bringing electrodes connected with the poles of a coil into contact with the skin, the first fact noticeable is that muscles in the neighbourhood contract; the next fact, and this should be clearly impressed on the memory, is that the muscles continue to contract.

This is noticeable also when the interrupted primary current is used, and serves to emphasise the observation which we have already made, in making or breaking contact with the continuous current, that variation—moderate or extreme (opening and closing circuit)—in a current is an essential to the development of the proper muscle function, viz., contraction.

But further observation will show that application of the electrodes to the nerve supply is sufficient to induce contraction of the muscle so supplied and stimulated, and thus we have demonstrated the most commonly used properties of the alternating current. These results are accompanied by the usual local congestion, and last only during the period of contact. The power of currents to relieve pain will be mentioned when the modes of electrical treatment are discussed.

Space will not permit us to do more than mention the experiments which, during the course of demonstrations given last year, we were able to show, proving—

(1) That with *small* alternating (medicinal) currents there is practically no electrolysis.

(2) That alternating currents control the functions of nerve and muscle.

(3) That though *sensation* may *appear* to be continuous, there are very marked differences between the effects of application of the alternating and continuous currents.

(4) That high potential alternating currents may easily be passed through a patient, though there be no contact with electrodes. This is not the case with continuous currents.

LESSON IX.

SKIN RESISTANCE.

IN dealing with the applications of electricity to the human body, a factor which demands our most careful consideration is *skin resistance.*

By many electricians this living protective insulation, in its ever varying degree in one direction or the other, is unfortunately too often ignored, or nearly so, for even in books purporting to be authoritative we read directions given as to the use of five, ten or more cells for the attainment of a certain object.

Now, independently of the difference in E.M.F. of different cells, and of the changes in potential that occur when the battery-charge runs down—which have been alluded to in earlier lessons—the resistance of the skin itself may vary from 40,000 ohms or more when dry, to 1,000 ohms or less when moist with perspiration, a continuous current being used. The differences with dry or moist skin when alternating currents are employed are not quite so great, but they are sufficiently so to make the condition of the skin a matter of much importance when we are using a current for curative purposes.

In a paper read before the Institution of Electrical Engineers on March 27 we have gone pretty fully into these questions, in so far as they concern battery-generated, continuous, and ordinary coil alternating currents, and in a further paper we have dealt with dynamo-generated continuous and alternating currents. (Trans. Brit. Assoc., Leeds, 1890.)

It is therefore unnecessary in these lessons that we should do more than impress upon the student, with a view to guarding against the dangers of shock or excessive electrolytic or other painful or even damaging action, the care that is needed to ensure, by the use of measuring instruments, that a current strength shall be no stronger than necessary, and, on the other hand, that it shall possess sufficient E.M.F. to overcome skin resistance and actually pass through the body from one electrode to the other. It is conceivable that a current generated by a battery, say, of ten or fifteen cells, shall, when the skin is moist, pass through the body to the extent of eight to twelve milliampères, while the same battery, when the same patient's skin is dry, may on another occasion scarcely send a perceptible current through the body at all. Between these extremes there are the intermediate conditions, in which, with a given E.M.F., a current of intermediate strength may be passed.

The natural condition of least resistance, viz., that which accompanies a state of free perspiration, may be, and is, commonly simulated by the use of salt and water solution.

In this case the period of soakage is important, for soakage extending over thirty to sixty minutes may diminish resistance to a tenth part of its original value.

As an illustration of the varying values of body resistance mainly due to the skin, we append the following table of observations made upon patients during actual treatment.

TABLE.

PARTS TREATED.	R. IN OHMS.
Lumbar region to ankle	1,200
Cervical region to sacral region	1,729
Through knees	620
Knee to foot	987
Through knees	1,225
Hand to hand	1,100
Foot to foot	1,125
Neck to feet	925
Neck to brachial plexus	833
Neck to hand	2,170

LESSON X.

Methods of Application—Medical, General and Local; Surgical.

THE methods of application of electricity to the human body are many and various. We will group them under two heads—viz., *A*, Medical; *B*, Surgical.

The former we take to be all those in which covered or padded electrodes are used, or those wherein both electrodes are applied externally; while the latter are those in which uncovered or bare electrodes are used, or wherein one or both electrodes are applied internally.

In all applications it is most necessary to proceed with great care and give minute attention to detail. The patient must be placed in suitable position and rendered as *comfortable* as circumstances will permit. The operator must be gentle, firm, prompt, and essentially "Nurse-like." The apparatus must be conveniently placed so as to be under the complete control of the operator, without disturbing the patient, and also so that the galvanometer or other measuring instrument in circuit may be easily read.

A.—Medical applications may be subdivided as (1) General, and (2) Local.

(1) General applications are made in such a manner that the whole body, or at least the nervous centres of the body, are brought in the direct line of electric influence. One of the most valuable forms of this method of application is that recommended by Doctors Beard and Rockwell, and called Central Galvanisation. They say, in their book on "Medical and Surgical Uses of Electricity":—

"The object in central galvanisation is to bring the whole central nervous system—the brain, sympathetic and spinal cord—as well as the pneumo-gastric and depressor nerves, under the influence of the galvanic current. One pole (usually the negative) is placed at the epigastrium, while the other is placed over the forehead and top of the head, by the inner borders of the sterno-cleido-mastoid muscles, from the mastoid fossa to the sternum, at the nape of the neck, and down the entire length of the spine."

A sponge or other well-padded electrode is held by the patient at the epigastrium, and the other electrode (preferably also a sponge, of medium size) is applied by the operator to the patient's forehead (centre), and a current of from $\frac{1}{2}$ to 2 *m.a.* passed for two minutes. Next the electrode is moved to the cranial centre (the hair having been previously wetted), and 2 to 6 *m.a.* passed for another two minutes. In like manner the operator then attacks the neck (front, sides and back), passing from 2 to 10 *m.a.* for about four minutes, and then proceeds to the spine, using a labile or stroking action along its whole length, passing from 5 to 15, or even 20 *m.a.* for another eight to twelve minutes.

The dose ranges from $\frac{1}{2}$ *m.a.* in the most sensitive parts to 20 *m.a.* in the least sensitive. Of course all cases will not be equally benefited by the same current strength, and there are many degrees within the range named which may be advantageously employed, but we do not think that more than 20 *m.a.* should be used unless under very exceptional circumstances. The period of duration of each application may also advantageously vary with individual cases. Messrs. Beard and Rockwell give fifteen minutes as the outside limit, but we find from experience that while a period of even ten minutes is fully enough for some patients, yet one of twenty minutes is distinctly beneficial to others.

General Faradisation is a somewhat similar method involving the use of coil currents. The term Faradisation is a bad one, as mentioned in a prior lesson, because it does not differentiate between the simple interrupted current (interrupted primary) and the alternating secondary current. Still, the process employed is the same in either case, and consists in passing, by means of a bare or thinly covered foot plate (on which the patient stands or rests his feet), and a padded handle electrode used labile by the operator, coil currents either interrupted or alternating, as the case may require, through the whole of the patient's body, starting with the head and working downwards in a manner similar to that used in central galvanisation, but including also the upper and lower extremities. In some cases it is more convenient that the patient should sit upon one pad, the legs being included, or not, in the labile applications according to circumstances.

When either of the above methods is employed it is very advantageous for the operator to make the applications to the *head and neck* with his hand or hands, including himself in the circuit for the purpose. If one hand only is used to apply to the patient, the other may simply hold the electrode, and thus complete the circuit through both patient and operator. If two hands are required for the patient, a pad electrode may be conveniently attached to the operator's neck.

The advantage of thus using the hand or hands as electrodes is that, owing to the adaptability of the hand to delicate gradations of pressure and contact area, the current strength administered may be regulated with great nicety to suit the susceptibility of the parts treated. The operator's own sensations are a useful adjunct to the measuring instrument employed in gauging the sensations of the patient, and further, many valuable manipulations may be carried out at the same time.

To the less sensitive parts this plan is unnecessary, for the comparatively strong currents—which may most advantageously be administered to the back—would be very disagreeable, and even painful, to the operator, if passed through his hands. A handle electrode should be used as a rule to all parts of a patient other than the head and neck.

Another very valuable form of general application is that known as the electric bath. This requires especial care, more particularly in the electrical arrangements, in order that leakage of the current may be avoided. The bath should be preferably of some non-conducting material, such as porcelain or hard wood, and must not be in metallic contact with the earth. That is to say, the supply pipe or pipes must not touch the bath, nor the water in the bath, and the waste-pipe must be insulated, by having a short piece of india-rubber tubing let in at some convenient section near where it leaves the bath. Unless some such means be adopted it is plain that when the water becomes electrified the current will leak away to earth along the pipe, which latter, being of metal and of large area, possesses very little resistance. For the same reason it is not advisable to use an enamelled metal bath, for though, if the enamel remain perfect, the insulation may be good enough, yet the moment there is the least flaw or chip all insulation is gone, and the bath becomes useless for electrical purposes. In some instances metal baths are used, the bath itself being made thus one large electrode, but this arrangement is not recommended now, owing to the electrolytic action between the electrified water and the metal, and other electrical difficulties. It is always well to avoid electrical complications as far as possible; therefore one of the first essentials of an electric bath is a well-insulated, non-conducting bath.

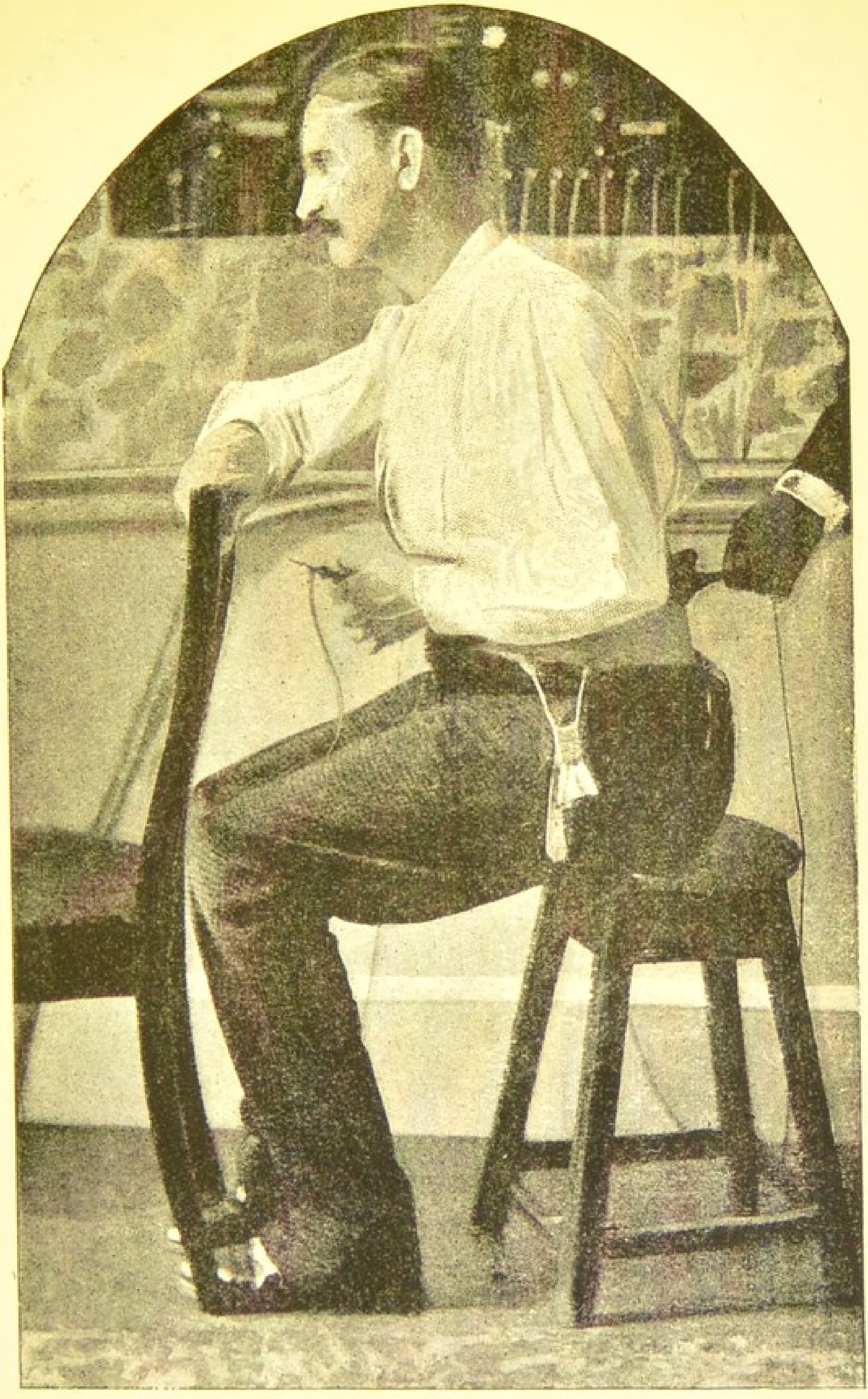
The water for filling the bath should be rendered a good conductor by the addition of salt or acid, preferably the former ($1\frac{1}{2}$lb. of common salt to thirty gallons of water will do), and should be of such temperature that the patient may remain immersed therein with comfort for from ten to fifteen or twenty minutes—about 98 degs. F. is best, but anywhere between 90 degs. and 100 degs., according to the fancy of the patient, will do very well. Suitable switches connected with the battery should be arranged on or near the sides of the bath, but out of the patient's reach.

The current should never be switched on till after the patient is in the water, and placed comfortably in position therein, and it should always be switched off again before the patient attempts to leave the water. If this be not done feeble or disabled patients might easily come into contact with one or both electrodes, and so receive a shock, involving unpleasant or even serious consequences.

If it is desired to electrify the water only, two large pad electrodes may be used, one being placed near the feet of the patient, not necessarily in contact with them, and the other near the head. The current should then be gradually turned on till the required C-*s* is arrived at.

This form of bath, though no doubt useful in some

PLATE II.



[to face page 84

cases, does not commend itself to us, for two reasons: first, because the water is generally a better conductor than the human body, and therefore nearly all the current passes through the water from electrode to electrode without entering the patient at all; second, because even if, owing to some change in the relative conductivity of the water and the patient, some appreciable share of the current does enter the body, it is impossible to measure how much, and thus the dose administered remains an altogether unknown quantity.

A better way is to put only one electrode in the water, preferably near the feet, and to place the other on some convenient part of the body which is just out of the water.

In most cases where a general tonic effect is desired, a good plan is to place one electrode in the form of a pad just under the nape of the neck as the patient lies back at full length, with the whole body, except head and neck, fully immersed in the water which carries the other electrode. A sling of webbing attached to the two sides of the bath, and rendered adjustable as regards length by a strap and buckle, enables this to be done satisfactorily. The sling being adjusted, the electrode is laid thereon, and the patient lies back, making good firm contact with the pad. In cases where this is not convenient, the neck pad may be tied in position by a piece of tape. In other cases, where desirable, one or both hands may grasp a conducting rod laid across the top of the bath. A very useful adjunct to any of the above is sponging the head, neck, and spine for a few minutes with a sponge electrode connected to one pole, while the other remains in the water, but *great care* is necessary in dealing with the applications to *the head.* Only a *very small* current must be used there, and every precaution taken to prevent shocks.

LOCAL APPLICATIONS.

A great variety of these are possible, and it is manifest that they must differ from each other mainly in accordance with the part on or in which it is desired to localise the current, and the nature of the trouble it is intended to alleviate or cure. We will instance applications for lumbago, for sciatica, for rheumatism in the arm, and for facial neuralgia.

In applying electricity for lumbago, the positive pole should be attached to a large pad electrode placed over the centre of the abdominal region, and the negative applied by means of a medium handle or sponge electrode to the lumbar region, being allowed to remain for some minutes over the special seat of the pain; 10 to 20 *m.a.* may be used, or practically as strong a current as the patient can bear, and this should be passed for ten or fifteen minutes at a sitting. Such sittings may, in acute cases, be repeated twice or thrice a day. Sometimes doctors order the coil current to be used for lumbago, and it should be applied in a similar manner, but should not be strong enough to produce violent muscular contraction. (Plate II. illustrates this method.)

For sciatica, several forms of application are used, each of which may or may not prove successful alone, and a combination of which is often advantageous. One form is to fix the positive attached to a large pad electrode upon the sacral region, using the negative handle labile along the whole line of the sciatic nerve and its chief branches, and giving special attention to the apparent seat or seats of pain. Sometimes the poles may be reversed with advantage. Another form is to use two-handle or sponge electrodes, and take the sciatic nerve in sections of a few inches from above downwards, or *vice versâ*, giving one or two minutes to each longitudinal section. Another form is to use two-handle electrodes, placing them as nearly as possible on either side of the nerve, and so pass the current transversely through it in sections. Sometimes very mild, and sometimes very strong currents are ordered, and no doubt each dose has its uses according to the requirements of the case. Coil currents may be used in a similar way.

Applications for rheumatism in the arm are made somewhat in the same way as those described for sciatica, care being exercised to so arrange the electrodes that the particu-

PLATE III.

lar nerve or muscle it is desired to influence shall be brought directly in the line of the current flow. Another form of application to the arm consists in placing the hand in a basin of water (or rather warm salt and water) together with one pole, and applying the other pole to the parts concerned by means of a sponge or handle electrode, or even fixing a plate or pad electrode upon the shoulder or the brachial plexus, or some other suitable spot, and allowing the current to pass steadily for the required time. Here again coil currents may be used in the same way. (Plate III. illustrates this method.)

Applications for facial neuralgia require very great care, and strict attention must be given to the direction of the current. It must be remembered that the negative pole seems to possess great local stimulating power to the nerves over which it is applied; and therefore, if, as in treatment of neuralgia, the object be to soothe and quiet an excited nerve, it is manifest that the negative pole must not come into the already excited region. A very good form of application for this trouble is to place the negative pole by means of a pad electrode on the nape of the neck, and then apply the positive by means of a small handle or sponge electrode to the seat of pain, and along the course of the nerve branches, giving special attention to their terminations. In doing this it is not well to use a stroking action, as the sensation is distinctly unpleasant under the circumstances. The electrode should be lifted and replaced on a fresh spot, *during which process the current should be switched off;* in fact, a series of small local and distinct applications should be made. Sometimes the negative pole may be advantageously placed over the sternum, or over the trunk line of the nerve just below and in front of the ear. In using coil currents in such cases, it is generally best to make applications to the nerve branches by means of the operator's hand and fingers, especially if he or she have knowledge of the massage movements suitable for combination with the electric treatment. (Plate IV. illustrates this method.)

Of the methods of application of static electricity it is unnecessary to say much. Great attention must be paid to the insulation of the patient, as if this be not good the electricity, owing to its high potential, will leak away to earth, and so be wasted.

Applications of static electricity are generally made with the patient fully clothed, and seated upon an insulated and insulating chair or platform. One knob or conductor of the machine is connected to the patient, and the operator holds, by an insulating handle, a metal electrode, which is connected to the other knob or conductor, near to the part of the patient's body it is desired to treat. This causes the passage of sparks between the electrode and the patient's body. In another method a large brush-like electrode is used. Here the passage of electricity takes the form of a breeze rather than a spark; the many points of the brush having the effect of spreading the discharge over a considerable area of the patient's body, so that it becomes far less concentrated. Sometimes the machine is connected to earth, and so a milder form of application is obtained.

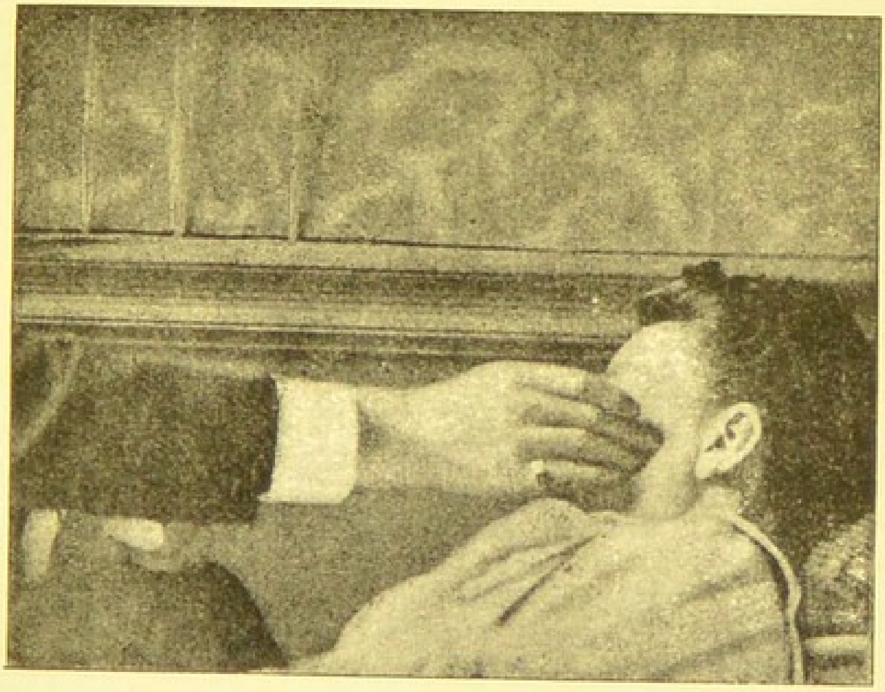
The above-named forms of application are given as typical instances of convenient and suitable methods. It will be readily understood that they may be advantageously modified or altered in a variety of ways in accordance with the necessities of each particular case. Rule of thumb applications should not be indulged in. The operator must first get a clear idea of the wishes of the prescribing medical man regarding the part or parts to be treated, the dose to be administered, and, if possible, the direct object of the treatment; then his or her own intelligence must decide upon the exact method to be employed and devise whatever modification may be needed to meet the circumstances of the case.

SURGICAL.

Our description of the methods of application of the bare or Surgical electrodes can in the present lessons, for obvious reasons, extend only to those typical instruments figured in a previous chapter (pp. 71, 73 and 74), viz.—

(1) The straight needle electrode (Fig. 37);
(2) The nævipunct (Fig. 38);
(3) The bougie electrode (Fig. 39).

PLATE IV.



The action of each of these is dependent upon the electrolytic function of the *continuous* current, which is used in most of the Surgical applications of electricity, to the exclusion of the interrupted primary and alternating currents.

(1) THE STRAIGHT NEEDLE ELECTRODE.

In order that this most useful modification of the bare electrode may be advantageously employed, it is necessary that one pole of the battery shall by means of a large pad or other electrode be kept in contact with some portion of the skin surface as near as conveniently may be to the site of the projected operation. This done, the other pole of the battery is by the aid of a flexible rheophore fixed by the terminal screw of the handle or holder, and the metal stem (*st*) with its needle (*b*) being *in situ*, our apparatus is ready.

Suppose we wish to remove a series of hairs from the face, and that we select the chin as our starting point. It will be advisable, for various reasons, that the pad should be connected with the positive and the needle with the negative pole. Arranging the former on the chest, or back, or using an electrode which can be grasped in the hand, the skin surrounding the particular hair selected is grasped between the thumb and forefinger of the operator's left hand. The needle is now inserted into the follicle beside the hair in such a way that its axis may be as nearly as possible that of the hair. The current is switched on to a strength of from two to five milliampères, and with the gentlest imaginable pressure the needle passes down the follicle beside and parallel with the hair until it reaches a point at which resistance is felt. Here further progress inwards must be suspended, for the point of the needle has reached the fundus of the follicle, and further insertion is not only needless, but harmful. Retaining the point in this position for a few seconds (fifteen to thirty will generally suffice), a fine effervescence will be noted at the point of entry. The needle may now be withdrawn, and grasping the hair with a fine forceps, it will be found to be perfectly loose, and should come away *without perceptible traction.*

If force be needed to withdraw the hair, the operation has not been properly done and will need to be repeated.

Care must be taken that the needle is passed *only along the follicle, and not forced through the skin;* also that careful note is made of the C-s employed, and the time occupied. Disregard of these points will lead only to failure, and may cause scarring—a matter of importance when the face is the part operated on. There should be *no* bleeding. (See Plate V.)

Other methods—for instance, grasping the *hair* with a forceps before passing the needle and using it as a *point d'appui*—are recommended in some well-known works ; but with an experience extending over the removal of many thousand individual hairs, the writers strongly recommend the former as being the only satisfactory and reliable one, having regard particularly to the prospect of complete and permanent destruction of the growth.

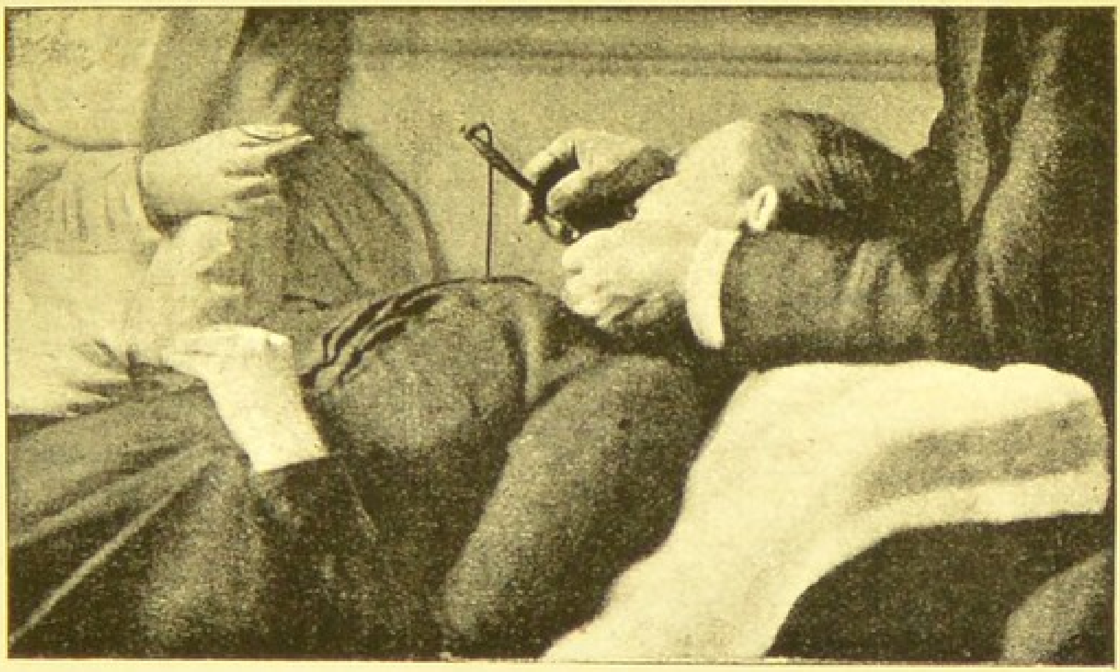
(2) THE NÆVIPUNCT.

The same instrument may be used in very similar fashion for the destruction of small growths, either on the skin or mucous membranes, and it is with the purpose of being able to attack nævus and other developments covering a larger surface that the nævipunct has been devised. This replaces the single needle, and, from the possibility of arranging the separate needles to cover *exactly* a surface of any shape (or size, the instrument being correspondingly enlarged, in so far as its area and number of needles is concerned), the necessity of repeated insertions of the instrument at a single sitting is obviated. Cases of port-wine stain of any extent may thus be satisfactorily treated.

(3) THE BOUGIE ELECTRODE.

The bougie electrode is an instrument of rapidly-increasing usefulness, and its proper, careful, and successful application in cases of stricture of rectum, urethra, and œsophagus is already well recognised as giving results far in

PLATE V.



advance of other and older plans of slow and rapid dilatation.

In such cases a pad is connected with the positive pole as before, and the bougie electrode by means of its screw (*r*) is placed in communication with the negative pole of the battery. The metal knob (*k*) being placed immediately at the seat of contraction a small current—two to six *m.a.* or more—is passed through the lesion for a period of one, two, three, or more minutes, as the nature of the case and the forbearance of the operator may dictate. The sittings may be repeated as frequently as needed for complete dilatation, and at such intervals as the experience of the operator may lead him to consider safe, but as operations such as these can only be performed by Surgeons, it is unnecessary to weary the reader with further detail.

The instances here given are intended only as typical examples of the numerous and frequently successful uses to which the Surgical electrode has been applied, and we trust that those who feel interested in this department of work will not be content with a superficial acquaintance with the methods recommended, but will take every opportunity of obtaining practical acquaintance, not only with the operations themselves, but with the management and control of the apparatus needed—for in scarcely any department of surgical work is a mastery of the instruments employed more imperative than in that at which our space permits us to take only a passing glance, and for which the future holds triumphs as yet undreamt of in our philosophy.

LESSON XI.

GENERAL HINTS ABOUT ELECTRICAL APPLICATIONS.

(1) ALWAYS test your battery and connections, so that you may be sure they are in working order, before touching the patient. A convenient method of doing this for the continuous current is to place both electrodes in the same vessel of water, or to touch them together, and thus completing the circuit for a second or two (not more), note the deflection of the galvanometer needle. If the needle deflects freely proceed to the patient; if it does not, examination of the connections, and perhaps of the battery, will be necessary. If there is no galvanometer in circuit apply some metal portion of the electrodes or rheophores to the tip of your tongue, and when the switch is turned on a peculiar semi-acid, semi-metallic taste will be at once noticed if the battery is working. This latter is only a very rough and ready test, but it is better than none at all. Coil currents, both interrupted primary and secondary, are best tested by bringing the electrodes into contact with some convenient part of your body, such as the hands, or one hand and some part of the arm.

(2) Make sure that the patient is conveniently placed with regard to the apparatus, so that after movement may be avoided as much as possible.

(3) See that the patient is as comfortable as circumstances will permit.

(4) Take your own position so that the switch board is well under your control, being particularly careful that you can see and easily read the galvanometer.

(5) Take care that the salt and water for moistening the skin and damping the electrodes is neither too hot nor too cold (about blood-heat is the best), and that the solution is not too strong; about half-an-ounce of common salt to a quart of water will do very well.

(6) When padded electrodes are used, wipe off superfluous water with a cloth before applying to the body, and do not let water run, drop, or splash upon the patient's clothes, especially upon underlinen.

(7) When any electrode or electrodes have to be fixed to the body, be careful to have them well tied, strapped or bandaged on, so that the contact may be firm and otherwise good.

(8) When using sponge or other handle electrodes use gentle but firm pressure. Too light a touch will cause irregular and uneven contact, which is very unpleasant and irritating to the patient.

(9) Never turn on all the current strength of the prescribed dose immediately, but starting with the smallest possible current, gradually increase it until the proper strength is reached.

(10) When the time of the prescribed dose is up, turn the current off gradually in the same way, and be sure that all the switches are turned off before you leave them.

(11) Remember that the sudden breaking of contact anywhere in the circuit means a shock to the patient, and is therefore to be most carefully avoided.

(12) Clean, wipe, and where necessary disinfect the electrodes immediately after use, and put straight in the room any disorder which the operation may have occasioned.

GENERAL HINTS ABOUT THE MANAGEMENT OF ELECTRICAL APPARATUS.

(1) Batteries should be kept in a dry, moderately cool place.

(2) Batteries of the Leclanchè type, which are kept ready charged, should be used regularly. They are far more likely to fail through faults developed by standing idle than to suffer by too much use. *Batteries of this kind should be used once a week at the very least.*

(3) Batteries, switch boards, connections, rheophores, and electrodes should be kept *scrupulously clean*, and all bright

metal parts should be frequently polished. Strict attention to cleanliness will often save much outlay for repairs.

(4) In all batteries using acid as an excitant, it is advisable, and in *most of them necessary*, that the zinc be not allowed to remain in the solution when the battery is at rest.

(5) If a battery refuses to work, look first for the fault in the connections. Test them ; clean and tighten them all and try again. If the fault still persists look to the fluid of the battery, which may be weak or exhausted ; then to the zincs, which may require re-amalgamating, or may be eaten up and useless ; and lastly to the carbon or other element.

(6) A saline solution is generally good to use as long as it exists at all, but an acid solution requires frequent renewal. Bichromate solution, which is the most common form of acid solution, always turns dark and green in colour when it is spent and useless.

(7) In coil batteries the vibrating hammer and contact spring require the most frequent attention. A little adjustment of the screws here will often suffice to remedy what seems to be an obstinate fault.

(8) Remember that in coils you have two distinct circuits to deal with. A fault in the primary circuit prevents both alike from working ; but a fault in the secondary will not necessarily disable the primary. As the primary circuit includes the battery and the vibrating hammer arrangement, it is evident that it is far more likely to contain the fault than the secondary ; but at the same time it must be borne in mind that the fault may be present in the latter.

(9) Never leave rheophores connected to the battery terminals, especially in portable batteries, because some sudden and unexpected movement may cause their ends to come in contact, and so the battery will be short-circuited and irretrievably damaged.

(10) Never let your galvanometer come near any magnet, or its movements will be disturbed and its records rendered worthless.

LESSON XII

(1) Indications for Use of Electricity in Medicine; (2) In Surgery. List of Books for Reference and further Study of the Subject.

IN the section on electro-physiology, we discussed the methods in which electricity, either continuous, interrupted or alternating, is supposed to act. It is unnecessary here, therefore, to do more than remind the reader of the catalytic, cataphoric, and electrolytic functions of the continuous current, and of the stimulating, sedative, and vaso-motor influence of the interrupted current, whether primary or secondary.

Some recent writers on electro-therapeutics have thought proper to disparage the use of the term *catalysis*. But bearing in mind the definition so clearly given to this term by Remak, we fail to see that it is other than most convenient, serving to obviate the use of much verbiage in the matter of naming individual " effects " of the applications of the continuous current.

It is now-a-days the fashion to object to the use of terms introduced by the masters of our science, but until something better is brought forward, we are content to follow in the wake of so great a leader as the celebrated German electro-physiologist.

Catalysis, then, may be used where we desire to improve nutrition, to promote circulation, to absorb effusions, to disperse glandular or other enlargements. In the latter instances the cataphoric function of the continuous current is probably of considerable aid in the process, and in all these cases it is advisable that a comparatively low current strength, with considerable electrode area, should be used for short periods. Particularly should this be remembered when applications are made to sensitive portions of the nervous system, or when the brain itself is the part under treatment.

Disregard of these points may induce unpleasant effects —headache, nausea, giddiness, trembling, &c.—and thus defeat the objects sought to be attained. In parts where skin, muscles, or abdominal viscera are to be influenced, the current strength may be larger, but even here most of the beneficial results may be obtained with currents under twenty milliampères.

But where the chief object is simple *cataphoresis*, it is not only permissible, but sometimes necessary that stronger currents should be employed. Again, where it is desirable to pass drugs, such as iodides, bromides, mercury, quinine, cocaine, chloroform, or others, through the skin, it is useless to attempt the process with any hope of satisfactory results, unless large electrodes (particularly the negative pad), and a current strength of twenty milliampères upwards to thirty or even more, is used, for from twenty to forty minutes or longer. In this manner it is possible with cocaine solution (ten per cent.) so to anæsthetise the skin, that a patient is able to bear the galvano-cautere without flinching.* In cases of local parasitic growth (ringworm, &c.), solutions of parasiticide salts have been passed by this plan so satisfactorily that a few sittings have sufficed to cure disease of considerable standing.

In rheumatoid arthritis and similar cases, treatment by cataphoresis is indicated, and the authors have found that this method has given results satisfactory to an unexpected degree. Further practical developments of cataphoric medication are in progress, and it is believed that by its aid it may become easy to apply *local* remedies in the treatment of disease to a much greater extent than has hitherto been possible.†

* In a recent case of rachialgia, Dr. Harries anæsthetised the skin in the region of the lower cervical and upper dorsal vertebræ so completely by this method, that he was able to apply the galvano-cautere deeply to six intervertebral spaces without any complaint of pain by the patient, either during or after the operation.

† It has just been brought to our notice that, at the recent International Medical Congress in Berlin, Mr. Edison, of New York, has described an experimental case of gout treated by this plan. It is only fair to ourselves to say that, previously to the experiment thus described, we had for months reduced this matter from the experimental to the practical stage, and both before and since Mr. Edison's attempt, have adopted "cataphoric medication" as a part of our daily work.

Concerning the indications for the use of the interrupted primary and secondary currents, and their effect in stimulating muscular contractions, in increasing general tone, relieving pain, and of their immense value to physicians in the confirmatory diagnosis of obscure nervous or other diseases, it is unnecessary in an elementary series of lessons to enlarge, for their use should be strictly limited to cases in which treatment is carried out under direct Medical supervision; and a catalogue of diseases would be neither interesting nor profitable here. It may be well, however, to state that the indiscriminate use of these powerful therapeutic agents—as indeed of the continuous current—may be fraught with danger to the patient and disappointment to the operator. And it is for these reasons that the use of electric appliances, so commonly and recklessly used by advertising charlatans, ignorant of the merest rudiments not only of Medical but of electrical science, should be avoided as one would the plague. As for the so-called electric "belts" and other "body-appliances," the less said the better. It is enough to state that most of them are incapable of sending a current through the resistance offered by the human skin—hence the necessity experienced by their vendors for constantly forcing them upon the public by means of the attractive but mendacious advertisements which disgrace the columns of many of our daily papers.

(2) In the Surgical applications of electricity the continuous current is always employed, unless under this heading we include those gynæcological operations in which the bare electrode is made use of, in the application of the alternating or interrupted current, as a stimulant to internal parts in relaxed conditions. Other than for these purposes, the continuous current is brought into play in treating many uterine states, whether they be due to inflammation, to injury during delivery, or to abnormal pregnancy (tubal, &c.).

In stricture of œsophagus, rectum, urethra or uterine canal, the electrolytic action of the continuous current has proved of the greatest benefit, not only as a palliative, but as a curative agent; and in those troublesome cases of enlargement of the prostate in which serious Surgical measures are often recommended, Dr. Harries has found the urethral electrode most efficacious in treating the condition.

Where it is desired to remove small superficial growths, whether on skin or mucous membranes, such as nævi, warts, fibrous and hairy growths, polypi, &c., there is no method which can compare with that which involves the subcutaneous insertion of needle or other electrodes.

Lastly, in aneurism, the coagulating influence of the current has been employed with variable success, but this operation is both difficult and dangerous, and from statistics of cases, it can scarcely be recommended even when used by operators expert not only in Surgery, but in electricity.

It is scarcely necessary to add that a most useful application of the continuous current is that form of it which is employed as a cautery. The galvano-cautère is both handy, cleanly, and manageable, and is much less likely to cause after-pain than the red-hot iron cautery, and its use is indicated where any form of cautery work is needed.

BOOKS RECOMMENDED FOR REFERENCE.

Electrical.

"Elementary Lessons in Electricity and Magnetism." By Prof. Silvanus P. Thompson, D.Sc. Published by Macmillan and Co. Price, 4s. 6d.

"Practical Electricity." By Prof. W. E. Ayrton, F.R.S. Published by Cassell and Co., Limited. Price, 7s. 6d.

Electro-Medical and Surgical.

"Medical and Surgical Uses of Electricity." By G. M. Beard, A.M., M.D., and A. D. Rockwell, A.M., M.D. Published by H. K. Lewis, Gower Street, London. Price, 28s.

"A Practical Introduction to Medical Electricity." By A. De Watteville, M.A., M.D. Published by H. K. Lewis. Price 9s.

"Practical Application of Electricity in Medicine and

Surgery." By G. A. Liebig, jun., Ph.D., and G. H. Rohé, M.D. Published by F. A. Davis, Philadelphia and London. Price, 8s. 6d.

"Electrolysis in Surgery, the Uses of." By W. E. Steavenson, M.D. Published by J. & A. Churchill, London, W. Price, 5s.

"Handbook for Operators in Medical Electricity and Massage." By H. Newman Lawrence, M.I.E.E. Published by Gill and Sons, Warwick Lane, London, E.C. Price, 1s.

QUESTIONS.

AUTHOR'S NOTE.—General answers to these questions are to be found in the text, but we wish it to be understood that complete answers to such questions can only be given after careful study of the subject in larger works.

LESSON I.

1. From which of the known forms of energy can electricity be obtained?
2. How may mechanical energy be transformed into electrical energy?
3. Give the name of a machine by which the re-transformation of electrical energy into mechanical energy may be accomplished.
4. What form of energy is transformed into electrical energy in a voltaic cell?
5. What is a thermopile?
6. How could you illustrate the completion of an energy cycle?
7. In any transformation of energy is all the initial energy available for work in its new form?
8. How do you reconcile the statements "Energy cannot be destroyed," and "In transformation and re-transformation much of the energy used to start with is lost in the process"?
9. What influence does the method of generation of electricity have upon its chemical, mechanical, thermal and physiological powers?
10. On what does the physical similarity of electric currents depend?
11. Wherein do electric currents differ from one another?
12. What are the chief characteristics required of an electric generator for Medical purposes?
13. Which form of generator best fulfils these conditions?

LESSON II.

1. What are the main points of utility which chemical electric generators should possess?
2. Describe a "simple voltaic cell."

3. In a voltaic cell what part or parts are used up in the process of generating electricity?
4. What is the positive plate of a battery cell? and which the negative pole?
5. Define the "elements" and "excitant" of a battery cell.
6. Of what character is the excitant of the Leclanchè cell —acid or saline?
7. What advantage does the agglomerate form of the Leclanchè cell possess over the more common form?
8. Describe the Daniell cell and show wherein it differs from the silver chloride cell.
9. What is the excitant in the bichromate cell and why should the zinc not be allowed to remain in the solution when the cell is not in use?
10. Wherein do secondary cells or accumulators differ from other battery cells?
11. What is meant by connecting battery cells "in Series," "in Parallel," and "in Groups"?
12. Sketch a battery of nine cells arranged in groups of three each.

LESSON III.

1. On what does E.M.F. depend?
2. With what phenomenon of hydrostatics may E.M.F. be compared?
3. Define Current-strength.
4. What is the effect of Resistance—and how is it overcome?
5. Name the practical units of measurement for E.M.F., current-strength and resistance.
6. Name the practical unit of current-strength for Medical purposes and state what relation it bears to the ampère.
7. State the name of the law which sets forth the relation between E.M.F., C-s, and R and write it down in the form of an equation.
8. Mention some of the uses of the application of this law in practical work.

9. On what does the E.M.F. of batteries depend?
10. When it is desired to obtain the maximum E.M.F. from a battery how should the cells be connected up?
11. What influence has the size of the elements upon the power of the battery?
12. When maximum C-s and minimum E.M.F. are required of a battery how should the cells be connected up?
13. What is meant by an electric circuit?
14. Name a few conductors.
15. What is the function of an electrode?
16. Why should electric conductors be insulated?
17. Is there any hard and fast line between insulators and conductors?
18. What are rheophores?
19. How would you know a switch board and what is its use?
20. Mention other names for "Terminals."

LESSON IV.

1. In what portion of a circuit would you expect to be able to transform electrical energy into work?
2. What relation would work done in such a transformation bear—(1) To resistance in circuit? (2) To the electrical energy expended in overcoming such resistance?
3. Give examples of *functions* of the continuous current.
4. What is osmosis? Illustrate your reply by a rough sketch of a simple method of demonstrating this phenomenon.
5. In what direction would you expect fluids to pass, supposing *osmosis* to be taking place through a septum placed between fluids of different densities?
6. Distinguish between *osmosis* and *cataphoresis*. By what simple arrangement might you prove chemically that cataphoresis was taking place?
7. In *cataphoresis*, is the direction of transference always that to be expected in *osmosis?* If not, what is the direction *always* taken by fluids in *cataphoresis?*

8. What is *electrolysis ?*
9. Give an example of chemical conditions, under which *latent* may be converted into kinetic energy. Does the energy thus set free always manifest itself in the same way?
10. What happens when a thermometer is placed in a fresh mixture of oil of vitriol ($H_2 SO_4$) and water?
11. Given a mixture of hydrogen and oxygen in the proportion of two parts H to one part O, in suitable apparatus. What would you expect to happen on passing an electric spark through the mixture?
12. Name the resulting chemical compound.
13. What are the accompaniments of the action taking place in such a mixture?
14. In the combination thus produced, what chemical process is illustrated? What term is applied to the converse chemical process?
15. What are the accompaniments of *analysis ?* and of *electrolysis ?*
16. Name the conditions requisite for the performance of electrolysis.
17. A continuous current being passed through a suitable conductor, in what way does decomposition of the fluid take place—as regards bodies set free at the respective poles?
18. What term is applied to bodies thus set free at the poles? At the positive pole? At the negative pole?
19. Sketch roughly one or more methods for showing the reactions (chemical) at the electrodes.
20. In the process known as *electro-plating*, at which pole would you expect the metal to be deposited?
21. Describe the *voltameter*. What happens when a continuous current (of sufficient E.M.F.) is passed through acidulated water contained in such an instrument?
22. What is *catalysis ?* What other functions of the current are included in *catalysis ?*
23. What are the leading points named by Remak as characteristic of catalysis?

LESSON V.

1. What is a *Continuous* current?
2. In what main characteristics do *Interrupted* and *Alternating* currents differ from continuous currents and from each other?
3. Name the apparatus commonly employed to change the continuous current of a battery into interrupted and into alternating currents.
4. Give a list of the chief parts of an induction coil, and state in general terms the nature of the work each has to perform.
5. Mention some of the ways in which the strength of an induction coil may be regulated.
6. Why is it not necessary to put the secondary wire of an induction coil in electrical connection with the primary?
7. If you had a primary coil with interrupting arrangement and battery complete and a sepırate movable secondary coil, how could you demonstrate the phenomenon of induction?
8. What change in the relative value of the factors E.M.F. and C-s is wrought by the use of an induction coil?
9. Why are the terms Faradic or interrupted as applied to coil currents objectionable?
10. How do magneto machines generate electricity?
11. What form of current do the magnetos supply?
12. How is Franklinic or statical electricity generated?
13. Describe a simple experiment for generating electricity by means of friction.
14. Wherein do influence machines differ from frictional machines?
15. Why are these machines (frictional and influence) difficult to keep in working order?

LESSON VI.

1. What are the factors of electrical dosage?
2. Why is it most necessary to measure the dose of electricity administered?

3. Name the instrument generally used to measure C-s, and state on what it depends for its action.
4. How should these current measureers be graduated?
5. What is the use of a voltmeter?
6. Which form of meter should be always in circuit with the patient during electrical applications (voltmeter or milliampère-meter) and why?

LESSON VII.

1. Why should rheophores be well insulated?
2. Name the two main classes of electrodes.
3. Describe a good covered electrode, dealing minutely with the construction of its parts and their respective use.
4. What is meant by a plate electrode? Give an illustration of its use.
5. Why is a fixed strap or band attached to a plate electrode objectionable?
6. Describe two or three convenient methods of connecting rheophores to electrodes.
7. On what point does the common sponge holder electrode fail in utility?
8. Give a list of the standard electrodes recommended by Erb, and name the diameter or surface area in each case.
9. Why should rectangular electrodes have their corners rounded, and why should pad covers always extend well beyond the edge of the metal?
10. What are *Bare* electrodes? How may they be classified? Give examples (*a*) of cutting electrodes; (*b*) of non-cutting electrodes.
11. Sketch a straight needle electrode. With which current is it employed?
12. What is the *electric nævipunct?* What advantages does it possess over the straight needle electrode?
13. Draw and describe a simple *bougie electrode.*
14. How would you arrange the electrodes for treatment of a stricture (say of the rectum)?

LESSON VIII.

1. When a sufficient continuous current is applied to the living skin *in the neighbourhood of muscles*, what happens—on completing circuit? on breaking circuit? on variation of current-strength? on maintenance of an unvarying current-strength?
2. Describe other phenomena occurring on the passage of such a current for a sufficient time.
3. After the passage of current of a certain given E.M.F for a certain period, the C-*s* as measured by the milliampère-meter is diminished. Why?
4. In Porret's experiment what fact is clearly demonstrated and what is implied?
5. What is meant by *Cataphoric Medication?*
6. Which form of current is used in the application of this method of treatment?
7. Is electrolysis possible with interrupted currents? with alternating currents?
8. Briefly, what are the Medical functions of the interrupted primary current?
9. What are the chief uses of the alternating current in Medical work? What is noted on application of coil current electrodes to the skin?
10. What is the striking difference in the results of continued application of electrodes in connection with continuous and coil currents respectively?
11. Must the electrodes necessarily be placed over the muscles, or will application in any other position produce similar results (as regards the muscles)?
12. Are small alternating currents capable of causing electrolysis?
13. What relations obtain between alternating currents and the functions of nerve and muscle?
14. Is it possible, *without contact*, to pass alternating or continuous currents through a patient?

LESSON IX.

1. What is skin resistance?
2. Why is the common method of prescribing electricity ("use 5, 10, or more cells") fallacious? Is it dangerous? Why?
3. In using currents for Medical or Surgical purposes what are the points that *must* be remembered?
4. What is the natural condition of least resistance?
5. How is it artificially produced for Medical applica-cations?
6. What is the average resistance from hand to hand?

LESSON X.

1. Why is it necessary for the operator to be so placed with regard to the apparatus that the milliampère-meter can be easily read by him?
2. Mention some forms of general application.
3. Describe in full the method of Central Galvanisation.
4. To what parts of the body should the hand or hands of the operator be used as electrodes when coil currents are used, and why?
5. Why are metal baths, even if enamelled, not suited for electric baths?
6. Describe carefully a method of administering an electric bath, and state the reason for each step described.
7. How would you proceed if ordered to administer 10 *m.a.* of continuous current to a patient suffering from lumbago. Name all the details of the process, and state the kind of battery you would use.
8. In administering electricity for facial neuralgia what special points require careful attention?
9. Describe briefly a method of application of statical electricity.
10. How would you arrange the apparatus for using the straight needle electrode? What precautions should be observed in hair electrolysis?

11. In what cases is the nœvipunct useful? Why?
12. In what class of cases is the bougie electrode applicable?

LESSON XI.

1. How would you test your battery and connections before making an application to a patient?
2. What is a convenient proportion of salt and water to use for moistening electrodes?
3. Why is it necessary to have electrodes which should be attached to the patient *firmly* fixed on?
4. How should current be turned on—suddenly or gradually, and why?
5. Why is it not well to allow batteries to stand idle for many days together?
6. What change in its appearance indicates that a bichromate solution is spent and useless?
7. What part of a coil battery is most likely to get out of order and consequently should be examined first when the apparatus fails in working?
8. Why should not rheophores be left connected to the terminals of batteries when not in use?

LESSON XII.

1. Under what circumstances is it advisable to make use of the *catalytic* function of the continuous current?
2. In order that this may be done how would you proceed. 1 In the matter of current-strength? 2 In that of electrode area?
3. What would be the average Cs employed for *catalysis?*
4. Would you use stronger or weaker currents for *cataphoresis?*
5. In *cataphoric medication*, name some of the drugs that it has hitherto been possible to use. Have any definite practical results yet been obtained by this method?
6. Would you expect the results of *cataphoric medication* to be *local* or *general?*
7. Name some Surgical conditions in which continuous current applications have been of benefit.
8. What are the advantages of the galvano-cautère?

GLOSSARY.

A.

ABSORBENT. Capable of imbibing; a vessel which imbibes, as the lacteals or lymphatics.

ACCUMULATORS. See Secondary Cells.

AGGLOMERATE CELL. A battery cell of the Leclanchè type, in which the binoxide of manganese is attached in a mass to the carbon element, and the inner or porous jar is dispensed with.

ALTERNATING CURRENTS. Those whose direction of flow changes rapidly, often many times per second.

AMALGAM. A pasty mixture of tin and mercury, or tin, zinc and mercury, which is applied to the rubbing cushions of frictional machines.

AMALGAMATED. Coated with Amalgam.

ARMATURE (OF AN ELECTRO-MAGNET). A piece of soft iron which is attracted towards and adheres to the magnetic poles during the time of magnetisation.

AMMETER. An instrument for measuring current strength and graduated in ampères.

AMPÈRE. The practical unit of current strength.

AMPÈRE-METER. See Ammeter.

ANALYSIS. The process of separation of a compound into its constituent parts.

ANIONS. The atoms which in Electrolysis move towards and attach themselves to the positive pole.

ANODE. The electrode attached to the positive pole in electrolysis.

ASTATIC NEEDLES. A pair of compass needles, so fixed relatively to one another that they are not influenced by the earth's magnetism.

ATTRACTION (ELECTRIC). The force which draws, or tends to draw, one charged body towards another body possessing a charge of opposite polarity.

B.

BARE ELECTRODE. The metallic ending of a rheophore, shaped according to necessity, used commonly for the performance of some Surgical operation.

BATTERY (ELECTRIC). An electric generator, consisting of one or more cells, either chemical or thermal.

BICHROMATE CELL. A battery cell having for its elements zinc and carbon, and for excitant a solution of bichromate of potash and sulphuric or hydrochloric acid.

BUNSEN CELL. A battery cell similar to the Grove, except that its elements are zinc and carbon.

C.

CALIBRATED. Corrected to a definite standard by direct comparison with a standard instrument.

CATALYSIS. A physiological process, dependent upon certain functions of the continuous current.

CATAPHORESIS. That function of the continuous current by which substances in solution may be conveyed through animal membranes.

CATAPHORIC MEDICATION. The method of treatment in which drugs are conveyed through the skin by aid of the continuous current (Harries).

CAUTÈRE (ELECTRO). An instrument by means of which electric currents are used for cauterisation.

CELL. A single complete chemical electric generator.

CHARGE (STATIC). The quantity of electrification produced by friction, or other means, upon the surface of a body.

COIL CURRENTS. Interrupted currents, either primary or secondary, obtained from an induction coil.

CIRCUIT (ELECTRIC). The system of conductors by means of which electricity flows (or is assumed to flow) out from and returns to the battery, or other generator.

COMBINATION. The chemical union of bodies to form a compound.

CONDUCTORS. Substances which will allow electricity to pass through or along them. Ordinary conductors are wires of copper, silver, iron, &c. The human body is also a conductor under certain conditions.

CONDUCTIVITY. The property which certain substances possess of allowing electricity to pass through or along them.

CONGLOMERATE. A mass of small particles cemented together.

CORE (OF AN INDUCTION COIL). A mass of soft iron, generally in the form of a bundle of wires placed in the centre of the coiled primary wire.

CONSERVATION (OF ENERGY). The doctrine which declares that the amount of energy in the universe is unalterable, and cannot be added to or destroyed by the act of man.

CONSTANT. Remaining unaltered during a given time.

CONSTANCY. The property of remaining constant.

CONTINUOUS CURRENT. That which flows in the same direction, without break or irregularity (other than a steady increase or decrease), for a given time. A continuous current is *not necessarily constant.*

COUPLES. The pairs of dissimilar metals, or like substances, which form the elements of batteries or thermopiles.

CURRENT (ELECTRIC). See current-strength.

CURRENT FLOW. Electricity passing from one point to another point, overcoming resistance, and involving the presence of E.M.F. and current-strength.

CURRENT-STRENGTH. The quantity of electricity flowing through or past any point in a conductor during any given time. Generally called current only, and represented by C in Ohm's Law formula.

CYCLE (ENERGY). A complete round or course of transformation and re-transformation of energy.

D.

DANIELL CELL. A battery cell, having for its elements zinc and copper, and for excitants dilute sulphuric acid and sulphate of zinc. It has two containing jars, one inner and one outer.

DIFFERENCE OF POTENTIAL. The difference of electric level between two points.

DISINTEGRATION. The separation of constituent parts of a substance.

DOSAGE. The measure of electricity as evidenced by current-strength and time.

DYNAMO. A machine for generating electricity by magnetic influence on coils of wire, which are caused to rotate or otherwise move in an electro-magnetic field by the aid of external power.

E.

ELECTRICAL EFFICIENCY. The ratio of the useful electric energy obtained from a generator or transformer to the total energy required to actuate such generator or transformer.

ELECTRICAL LEAKAGE. The escape of electricity from its proper conductor.

ELECTRIC GENERATOR. A machine or apparatus which acts as a primary source of electricity by reason of processes set up within itself, either with or without extraneous aid.

ELECTRO-CHEMISTRY. Those chemical processes which are dependent upon electrical action.

ELECTRO-CAUTÈRE. See Cautère.

ELECTRODES. The conducting media of many forms which are used to conduct the electricity to the patient by direct contact.

ELECTROLYTE. Bodies which suffer chemical decomposition during the passage of electric currents through them.

ELECTROLYSIS. The process of chemical decomposition by means of electric currents.

ELECTRO-MOTIVE FORCE. That which is produced by the difference of potentials at the poles of a generator, and by which the current overcomes resistance and flows through or along a conductor Generally written E.M.F.

Electro-Motor. A machine which, being supplied with electrical energy, gives out mechanical energy.

Electro-Physics. That department of science which deals with the physical properties and functions of electricity.

Electro-Static Charge. See Charge.

Elements (of a cell). The strips or plates of dissimilar metal or other material, which are used in chemical and thermal generators of electricity.

E.M.F. See Electro-Motive Force.

Energy (Electrical). Power to do work by means of electricity.

Excitant. The fluid or fluids used to act upon the positive element in a chemical generator of electricity. Also called the exciting solution.

Exciting Solution. See Excitant.

External Action. The action in an electric circuit, other than the internal action of the generator.

F.

Faradic Electricity. An incorrect term used to denote coil currents. It is misleading because it does not differentiate between the interrupted primary current and the secondary alternating current.

Faradisation. An inaccurate and imperfect term for the act of electrifying with coil currents. See also Faradic.

Field (Magnetic). The space influenced by magnetism, and said to be traversed by magnetic lines of force.

Franklinic Electricity. Electricity generated by frictional or influence machines.

Frictional Machines. Those which generate electricity by means of friction.

G.

Gaiffe Cell. A form of silver chloride cell.

Galvanic Electricity. Electricity generated by chemical means. Called also Voltaic Electricity.

GALVANISM. The use of galvanic or voltaic electricity; more correctly, the use of continuous currents as distinct from interrupted or from alternating currents.

GALVANISATION (CENTRAL). A method of treating the great nerve centres of the body with continuous current.

GALVANOMETER. An instrument for measuring electric currents by means of their action upon a suspended or pivoted magnet.

GALVANOMETER NEEDLE. The small magnet or pointer attached thereto in a galvanometer, whose deflections upon a graduated scale denote the magnitude of the current passed through the instrument.

GENERATION (ELECTRICAL). The process of development of electrical force.

GENERATOR (THERMAL). A generator of electricity by means of heat.

GROVE CELL. A battery cell having for its elements zinc and platinum, and for its excitants strong nitric acid and dilute sulphuric acid.

I.

INCANDESCENT. That which by reason of its intense heat gives out light without flame.

INDUCTION. The electric influence which interrupted or varying currents exercise upon conductors and other currents brought near to them.

INDUCTION COIL. An apparatus which transforms currents of low E.M.F,, and comparatively large current-strength, into interrupted and alternating currents of high E.M.F. and small current-strength.

INFLUENCE MACHINE. A machine which generates statical electricity by means of the electric influence of a small charge, either residual or communicated.

INSULATION. That which isolates or confines electric currents and charges in such a manner that they do not escape from their proper conductors.

INTENSITY OF CURRENT. An incorrect expression relating to a current due to high E.M.F.

Internal Action. That action in an electric circuit which takes place within the generator.

Internal Resistance. The resistance to current flow within the battery or other electric generator as distinct from the resistance of the external circuit.

Interpolar. Between the poles.

Interrupted Current. That which while still flowing in one direction is stopped and started again at more or less regular intervals, and generally with great rapidity. The current from the primary wire of an induction coil.

K.

Kathode. The electrode attached to the negative pole in electrolysis.

Kations. The atoms which in electrolysis move towards and attach themselves to the negative pole.

Key. A mechanical arrangement by means of which an electric circuit may be closed or opened at will.

Kinetic Action. We speak of " Kinetic Force " when potential or latent force has been developed into its active form.

L.

Labile. Moving with a stroking motion.

Latent—Hidden. This term is equivalent to potential (not used electrically).

Leclanchè Cell. A battery cell having for its elements zinc and carbon, with binoxide of manganese, and for its excitant a saturated solution of sal-ammoniac or sodium chloride.

Lymphatics. The small vessels by which the secretions of the lacteal vessels and intercellular spaces are conveyed into the general circulation.

M.

Magnetic Compass. An instrument for determining the direction of the magnetic north pole by means of a magnetised light steel needle pivoted or suspended above a card marked with the points of the compass.

MAGNETIC FORCE (LINES OF). The main directions of influence in a magnetic field.

MAGNETO-MACHINES. Machines for generating electricity by the influence of permanent steel magnets on coils of wire which are caused to rotate or otherwise move in a magnetic field by the aid of hand or other power. Medical magneto-machines usually generate alternating currents.

MARIE DAVY CELL. A form of sulphate of mercury cell.

MILLIAMPÈRE. The one thousandth part of an ampère and the unit of current-strength for Medical purposes.

MILLIAMPÈRE-METER. A galvanometer which measures the current-strength in milliampères.

MINOTTO CELL. A battery cell of the Daniell type in which the copper element is placed as a plate at the bottom of the containing jar and is separated from the zinc by a loose packing of sawdust or sand saturated with dilute sulphuric acid. Only one containing jar is thus needed.

MOTOR. The machine or engine which puts another machine in motion.

MULTIPLE ARC (IN). A term synonymous with parallel as a method of connecting up battery cells.

N.

NÆVIPUNCT. An instrument designed by Dr. Harries for obviating the necessity of repeatedly puncturing the skin in certain operations—and consisting of several needles connected electrically, with an insulating stem.

NEGATIVE POLE. That pole by means of which electricity returns or is assumed to return to the generator.

O

OHM. The practical unit of resistance, being 10^9 absolute units of resistance.

OHM'S LAW. The law regarding the relation between

E.M.F. current and resistance. It declares that the current in ampères equals the E.M.F. in volts divided by the resistance in ohms.

OSMOSIS. The physical principle by which fluids of varying densities traverse animal membranes.

P.

PARALLEL (CELLS IN). The method of "connecting up" battery cells for quantity, the elements being arranged positive to positive and negative to negative.

PHYSIOLOGICAL. Relating to the *functions* as distinguished from the *structure* of a living body.

PLATES (OF A BATTERY). The metal elements when the strips are flat and of large area.

PLATE ELECTRODES. Those consisting of flat sheets or strips of metal.

POGGENDORF. The inventor of the bichromate cell.

POLARISATION. In a battery cell the tendency to a reverse current opposing the main current.

POLARITY (OPPOSITE). The electrical condition of opposition in comparing one pole with another.

POLES (OF A BATTERY). The terminals or wires which conduct the electricity out from and back to the battery.

POROUS JAR. A jar of porous material standing within the outer containing jar of a battery and having within itself one of the elements.

POSITIVE POLE. That pole by means of which electricity flows, or is assumed to flow, out from the generator.

PORTABLE BATTERY. A battery complete in itself which is capable of being moved or carried about without difficulty.

POTENTIAL. Electric level, differences of which set up electro-motive force, or electrical pressure.

PRESSURE. See Potential.

PRIMARY CURRENTS. Direct currents passing through the primary coil or wire.

PRIMARY WIRE. A part of the external circuit directly connected with the poles of an electric generator.

PURE. Chemically free from admixture.

Q.

QUANTITY (OF ELECTRICITY). The current-strength passing as measured in units of time.

R.

REACTION. The chemical change or changes taking place when substances capable of chemical action upon each other come together under suitable conditions.

RESISTANCE. That property of bodies which renders them bad conductors of electricity.

RE-TRANSFORMATION. The conversion into its original form of a mode of motion, *e.g.*, heat into electricity (thermopile) and back again into heat (cautère).

RHEOPHORES. Conducting wires of convenient length, and arranged for easy attachment to battery, switch board or electrode.

S.

SAL-AMMONIAC. A solution of chloride of ammonium ($NH_4\,cl$).

SALINE. A compound of an acid with one of the alkalies.

SATURATED. Holding in suspension as much as possible.

SECONDARY CELLS. Cells which have to be charged electrically before electricity can be obtained from them.

SECONDARY WIRE. The fine wire composing the secondary circuit of an induction coil.

SECONDARY CURRENTS. Currents produced in the secondary wire. These are opposite in direction to primary currents.

SEPTUM. By the term as employed in these lessons we mean a piece of animal membrane interposed between solutions of different densities.

Series (Cells in). The arrangement of battery cells in such a way that the positive element of one is connected to the negative of another and so on.

Self Induction. The electric influence which interrupted or varying currents exercise upon their own conductors especially when such conductors are wound in a coil.

Short-Circuit. Used as a verb to express an unintentional shortening of the external circuit, so that its resistance becomes a minimum.

Silver Chloride Cell. A battery cell having for its elements zinc and silver chloride, and for its excitant chloride of zinc or of sodium.

Skin Resistance. That insulating property of the skin which renders it a bad conductor of electricity.

Stabile. A term the converse of "labile," implying steady application of an electrode to a part.

Statical Electricity. Electricity of high potential and small current-strength, usually generated by a frictional machine.

Storage Cells. See accumulators.

Sulphate of Mercury Cell. A battery cell, having for its elements zinc and carbon, and for excitants sulphate of zinc and sulphate of mercury.

Switch. An arrangement for making or breaking a circuit.

Switch Board. A board upon which are arranged one or more switches.

Synthesis. The process of chemical combination, which results in the production of a chemical compound.

T.

Telephone. An instrument arranged so as to admit of the propulsion of sound (by electrical aid) to great distances.

Terminals. The extremities of a rheophore or other conductor.

Thermopile. An arrangement for converting heat into electricity.

TRANSFERENCE (MECHANICAL). The actual passage of substances from the positive to the negative pole by aid of the continuous current.

TRANSFORMATION (ELECTRICAL). The conversion of electricity from one form into another, *e.g.*, from *continuous* to *alternating*.

TRANSMUTATION. The process of changing one mode of motion into another; *e.g.*, *heat* into *electricity* and *vice versâ*.

U.

UNITS. Standards for measurement—of time, strength, resistance, &c., &c.

V.

VOLT. The unit of electromotive force.

VOLTAIC ELECTRICITY. That form of electricity which is generated by a voltaic battery.

VOLTAMETER. An instrument for measuring current-strength by the electrolytic decomposition of fluids.

VOLTMETER. An instrument for measuring differences of electric potential.

VULCANITE. A hardened product of the treatment of india-rubber with sulphur, by which certain of its properties are improved.

INDEX.

A

D

ELECTRICITY IN MASSAGE.

NOTE.—As it is often claimed that Electricity is passed from the rubber to the rubbed in the operation of Massage, we have been asked to add such information as we possess relating thereto. To that end we think we cannot do better than give a short extract from a paper we recently had the honour of reading before the "Society of Arts":

"While on this portion of our subject, it might be well to refer to some experiments we have made to determine whether electricity can be passed from rubber to rubbed in the act of massage. For this purpose, several readings were taken from both operator and patient before and after the operation; and it was found that, while in all cases the patient gained electrically by the rubbing, in most the operator gained also. In some other cases, though the operator gained nothing, or even lost a little, the loss was not at all proportionate to the gain of the patient. These results, we think, are amply accounted for by the fact that exercise seems always temporarily to increase the body currents, provided it be not sufficiently violent or long sustained to cause exhaustion. Massage acts upon the patient by improving the circulation and emptying the lymphatics, and so, to that extent, is akin to gentle exercise; hence the increase of the body currents noted in the patient. Massage is to the operator often more than gentle exercise, and is frequently accompanied by a certain amount of exhaustion. Any gain in body current on the part of the operator is probably due to the exercise taken; but this gain may be rendered negative by accompanying exhaustion. We are thus led to conclude that electricity does not pass from rubber to rubbed in massage."

Peptonised Milk is Sweet & Palatable

WHEN PREPARED AS DIRECTED WITH

ZYMINE (Extractum Pancreatis) FAIRCHILD.

ITS PREPARATION

Costs Less than a Penny a Pint.

ZYMINE (EXTRACTUM PANCREATIS), Fairchild,

Is a *Dry Powder*, containing in the most active and concentrated form all the Enzymes of the Pancreas.

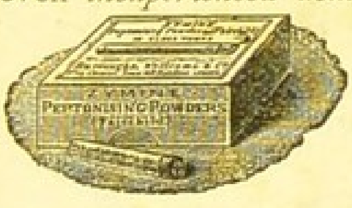
IT WILL DIGEST ALL KINDS OF FOOD: 5 grains, with a little soda, will sufficiently peptonise a pint of milk in a few minutes; 30 grains, with a little soda, will peptonise 4 oz. of beef, producing a concentrated, nutritious and delicious beef tea.

ZYMINE PEPTONISING POWDER (Fairchild)*

IN GLASS TUBES.

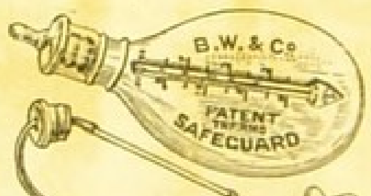
Is the most convenient form for preparing peptonised milk, gruels, jellies, custards, blanc-manges, &c., &c.

THE INSTRUCTIONS given in one of the direction slips enable even *inexperienced domestics* to quickly prepare any peptonised food.



One tube added to a pint of cows' milk so pre-digests it that it will no longer form a curd to irritate and inflame the infant or invalid stomach. They render cows' milk precisely like mothers' milk. "The introduction of which has probably done more than any other therapeutic measure of recent times to lessen infant mortality."—*British Medical Journal.*

These Powders are admirably adapted for use with the B. W. & Co. Thermo-Safeguard Feeding Bottle, pronounced by the *Edinburgh Medical Journal*, "**the best of all feeding bottles.**"



This Bottle differs from all others in the fact that a thermometer, which instantly registers the temperature of the food, is embedded in the glass. In addition, the bottle possesses the advantage of being graduated in ounces, so that the precise amount of food administered can be known, thus tending to avert the evil of over-feeding.

"It has a great deal to recommend it."—*British Medical Journal.*

While the Zymine Peptonising Powders are the most *elegant* and *convenient* form for peptonising milk, they are somewhat more expensive than the simple Zymine; where cheapness is of first importance the latter may therefore be used.

*** Beware of imitations of these Peptonising Powders. Always see that the name FAIRCHILD is on the package, as substances of an entirely different character are being sold in the market under the name of Peptonising Powders.**

The above are supplied at Moderate Prices by Chemists everywhere.