THE

MEDICAL AND SURGICAL

USES OF ELECTRICITY

BY

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PREFACE

THIS work is practically the ninth edition of Beard and Rockwell's "Treatise on the Medical and Surgical Uses of Electricity," but Dr. Beard has been long dead and has had no connection with any of the revisions since the second. It has been thought proper, therefore, to issue the work as it now stands under the name of the present writer alone. The book has been thoroughly revised and much of it rewritten, the old stereotyped plates having all been destroyed. The illustrations have been newly drawn and many new ones added, so that the author again offers to the profession a treatise fully up to the times. Electricity in its relation to medicine as well as to commerce having in recent years been wonderfully progressive, the present issue bears little resemblance to the earlier editions. In but one respect has there been little change: the general therapeutic action of electricity and its influence over nutrition. It was the enunciation of the idea that electrization, besides being merely a local stimulant, exercised an influence over general and local nutrition at once unique and unrivalled, together with descriptions of the methods by which these nutritional effects are best obtained, that gave to the work the popularity and vitality it has had abroad and at home. It is this fundamental idea of the nutritional effects of electricity upon which in great measure must be based its utility in medicine. Among the new chapters is one devoted to the Röntgen or X rays, while the interesting subject of static electricity has been entirely rewritten and greatly enlarged. But to indicate the many additions and omissions in recasting this work would be a tedious and unnecessary task. We would simply call attention to the fact that all the descriptive cases have been omitted, thus giving space for new and valuable material which would otherwise have swelled the volume beyond reasonable size.

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CONTENTS.

ELECTRO-PHYSICS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

ELECTRO-PHYSIOLOGY.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

ELECTRO-THERAPEUTICS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXXII.

ELECTRO-SURGERY.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

LIST OF ILLUSTRATIONS.

ELECTRO-PHYSICS.

CHAPTER I.

A KNOWLEDGE OF THE PRINCIPLES OF ELECTRO-PHYSICS NECESSARY TO THE ELECTRO-THERAPEUTIST—DEFINITION OF ELECTRICITY—MAGNETISM.

Electro-physics is the science which treats of electricity in its physical relations.

No one can be a master in electro-therapeutics without also being a master in electro-physics. Hence it becomes necessary, in a systematic treatise on electro-therapeutics, to present the leading principles of electro-physics, and to point out their practical bearings both on electro-physiology and electro-therapeutics. This necessity is all the greater because electro-physics is the branch of electrology that electro-therapeutists are most of all disposed to neglect; and ignorance of this department has retarded, and still retards, the scientific advance of electro-therapeutics, both medical and surgical. It is possible to make happy hits in electro-therapeutics without knowing anything of electro-physics or electro-physiology; but on the average, and in the long run, the best results will be obtained by those who to purely practical knowledge add a thorough mastery of the scientific relations of the subject.

Why Discussed in a Practical Treatise Like This.—The necessity of presenting the leading principles of electro-physics in a practical treatise like this is the more imperative from the fact that, until quite recently at least, all, or nearly all, the text-books on physics in use in schools and colleges have failed to represent the advanced researches and generalizations of modern scientists in the department of electricity.

To this should be added the consideration that any science, however well acquired, if it be not kept before the mind by teaching or writing or by practical application, soon fades from the memory, or becomes a mass of half-truths and uncertainties. We are therefore justified in assuming that not one in a hundred of those who will consult this book as a guide in electro-therapeutics will be so thoroughly and accurately informed on the principles of electro-physics as not to need, on this subject, some compact treatise which shall serve as a guide and reminder of the leading facts and principles of the science. To supply this need is the object of this division of our treatise.

NATURE AND DEFINITION OF ELECTRICITY.

Electricity is now regarded as a force correlated to the other great forces of nature—heat, light, etc.—and, like them, is simply a mode of motion—a form of vibration.

Although the precise nature of these vibrations have not yet been mathematically demonstrated, as in the case of light and heat, yet the theory that the phenomena of electricity are the result of vibrations has much in its favor, and it is by no means impossible that in the future the nature of these vibrations will be well understood.

In the present treatise, as in all works on physics, various terms, as "current," "flows," "runs," etc., that took their origin when the fluid theory prevailed, are retained for the sake of convenience of description. With this understanding there is no objection to their use.

Electricity is manifested in three general forms: Magnetism; static or frictional or franklinic electricity; and galvanic or voltaic electricity.

MAGNETISM.

Magnetism.—In order to understand electricity in general it is necessary to understand magnetism, which is one of its manifestations. Magnetism, defined by its phenomena, is the polar effect which certain bodies possess of attracting iron. The bodies which are observed to have this power are called magnets, and are divided into two classes—natural and artificial. Natural magnets consist of iron ore or loadstone. Loadstone was first discovered in Magnesia, in Asia Minor, and hence the name magnet was derived. The compass was introduced into Europe in the twelfth century; but the Chinese are said to have been acquainted with it in the fourth century.

Artificial magnets are usually made of steel that has been magnetized by the galvanic current or by other magnets. Steel bars that have been thus magnetized may be either straight or bent. For convenience sake, they are usually bent in the form of a horseshoe.

All substances are more or less susceptible to magnetic influence, but iron is more affected by it than others. Experiments illustrative of the effects and powers of artificial magnets are so familiar that they need not be cited.

Polarity of Magnets.—The polarity of a magnet is that peculiar property by which it manifests two opposite conditions, that are termed, relatively to each other, the north and the south pole. When a magnetic needle is so suspended that it can move unimpeded in any direction, one end points to the north and the other to the south. If the magnet be disturbed in any way, and forced temporarily out of position, it at once and uniformly returns.

Polarity is a quality that belongs not only to magnetism, but also to other forms of electricity, and to light and the other great forces.

The poles of a magnet are always at its ends, for here the attractive power is greatest. This can be demonstrated by a very simple experiment. If a magnetic bar be rolled in a pile of iron filings, it will be found that these adhere to the bar most firmly and in the greatest quantity at or near its poles. The quantity that adheres is less as we approach the middle of the bar.

Neutral Line.—In long bars there is always a place at the middle, or near to it, where no filings are attracted. This space is variously termed the neutral or magnetic zone, or magnetic equator, or point of indifference.

Another familiar experiment is to pass an iron ball, suspended by a string or thread, near to a magnet from end to end. It is observed that

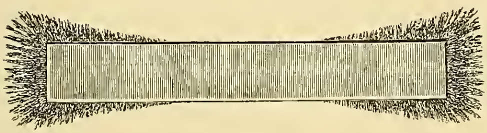

FIG. 1.

the ball is attracted very little, or not at all, in the middle, but that the attractive power is increased as we bring it toward either end. If any substance be placed between the ball and the magnet, the attraction is just as marked, unless the interposed substance itself contains iron. Nearly all substances that are not themselves magnetic are capable of transmitting the magnetic influence.

Another feature of magnetic polarity is that like poles repel, and unlike poles attract, each other. If one magnetic bar be suspended freely in the air, and another be brought near to it, it will be found that the north pole of one is attracted by the south pole of the other, and *vice versa*—in short, that the like poles repel, while the unlike attract.

Magnetism of Broken Magnets.—If a bar that has been magnetized be broken in the middle, each half will have two poles and a neutral point in the centre. If one of these halves is broken in the middle, each half will be found to have two poles and a neutral line. If one of these parts in turn be broken, each half will again be found to be a complete magnet, with two poles and a neutral line, and so on as long as we can carry the division.

Coulomb's Theory of Magnetism.—A theory of magnetism advanced by Coulomb is, that magnetic substances consist of particles, each one of which is a magnet. These particles have their poles turned in different directions, so as to neutralize each other.

Magnetization brings these particles round so that they lie in the same direction. This theory brings magnetism very close to static electricity. and would naturally be adopted by those who believe all magnetic phenomena result from electricity in magnetic bodies.

Between the behavior of electricity in animal bodies (animal electricity), electricity in general (static and dynamic electricity), to be subsequently explained, and magnetism as here explained, there are analogies so close and so consistent as to warrant the view that all are but different manifestations of one force.

Magnetic Induction.—If a bar of soft iron is brought in contact with or near to one of the poles of a magnet, it is attracted, and for the time being becomes itself magnetic; and if it is brought near enough to the magnet, it firmly adheres to it. A bar of soft iron thus obtains by induction all

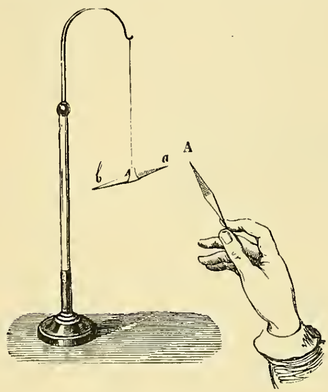

FIG. 2.

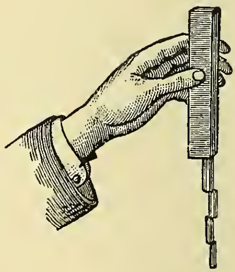

FIG. 3.

the properties of an ordinary magnet. It has a north and south pole. It attracts iron filings around these poles, just like the regular magnet. If another piece of soft iron is brought in contact with or near to its poles, it is attracted and made to adhere, just as it would do if applied to an or dinary magnet. Quite a number of bars of soft iron.(Fig. 3) may be made to adhere in the same way. But when this bar, thus made magnetic, is forcibly removed from the permanent magnet to which it adheres, it instantaneously loses all its magnetic power, and the iron filings or pieces of soft iron that have been attracted by it at once drop off. Such a magnet is therefore styled "temporary," in contradistinction to the permanent magnets of steel.

If a bar of steel is brought near to, or in contact with, a magnet, it also becomes magnetic, and exhibits very different phenomena from the bar of soft iron. In the first place it becomes magnetic much more slowly than the bar of soft iron, and displays less magnetic power. On the other hand it does not, like the soft iron bar, lose its attractive power as soon as it is removed from the magnet, but permanently retains it.

The quality of steel by which it at first resists the attractive power of magnets, and resists the dispersion of the magnetism which it has once acquired, is called coercitive force.

The same phenomena are observed in regard to heat. Some bodies that are quick to acquire heat are quick to part with it; and *vice versa*, those bodies which, like iron, steel, and so forth, acquire heat gradually, also part with it slowly.

It is by virtue of its coercitive force that loadstone permanently retains its magnetism.

The harder any steel is the greater its coercitive force. Steel that is soft has comparatively little coercitiveness, and when brought near to, or in contact with a magnet, it behaves very much like soft iron. Very hard steel, on the contrary, has so great coercitiveness that it is only attracted by very powerful magnets.

Soft iron, when adulterated with sulphur, phosphorus, arsenic, or charcoal, or if it is even twisted or bent, may exhibit a slight degree of coercitive force. Soft iron that is perfectly pure possesses no coercitive force whatever.

The law of the distribution of magnetism in a bar of iron, and the law of magnetic attraction and repulsion were discovered by Coulomb in 1789.

Shape of Magnets—Magnetic Armatures.—Artificial magnets are either composed of straight bars or are bent in the shape of a horseshoe. The horseshoe form is used mainly for the sake of convenience. It enables us to apply both poles simultaneously and uniformly to the object that is to be magnetized. Very powerful magnets may be made of a number of thin steel bars placed side by side, their poles being situated homonymously, that is, lying in the same direction. A number of bundles of bars of steel arranged in this way is called a compound magnet or laminated magnet.

Magnetic armatures (A, B, Fig. 4) are pieces of soft iron that are

FIG. 4.

placed at the ends of magnets to keep their magnetic power. This bar, or armature, not only receives magnetism from the magnet, but acts upon it in return, and thus helps to preserve its magnetic power. Magnets that are not provided with an armature gradually lose their attractive power by the disturbing influence of the magnetism of the earth. The magnetic power of magnets is apt to be impaired by letting them fall on a hard surface, or by suddenly striking them with a solid body.

Magnetization.—It is possible to communicate magnetism to bodies that can retain it in several different ways:

1. *By Single Touch.*—The bar which we wish to magnetize is laid on a table, and the pole of a magnet is rubbed along its surface from end to end for a number of times.

2. *By Double Touch.*—The bar that is to be magnetized is placed on a piece of wood, the ends of which are placed against two strong magnets. Two magnets for rubbing are placed on the bar to be magnetized, making an angle with the bar of from 15° to 20°. A small piece of wood is placed between the extremities of these two magnets, to prevent their touching. They are then rubbed along the bar that is to be magnetized, from the middle toward the end and back again, and raised from the magnetized bar again at the middle. This method communicates a strong though sometimes irregular magnetism; it was invented by Mitchell, and perfected by Epinus in 1758.

3. *By Separate Touch.*—This method consists in putting two opposite poles of two magnets of the same force in the middle of the bar that is to be magnetized, and moving each of them at the same time toward the opposite end of the bar. This operation is repeated several times on both sides until the bar is magnetized.

The magnets may be held vertically or may be inclined.

The vertical method was first used by Knight in 1745.

4. *By the Galvanic Current.*—The bar to be magnetized is placed inside a coil of insulated wire through which a galvanic current is conducted, and is then moved backward and forward, as in the method by the double touch.

5. *By the Earth.*—It is clear that the earth is itself a magnet, for it manifests strong inductive power. A steel rod becomes permanently magnetic when it is held parallel to a dipping-needle. If a bar of soft iron is held in the same position it also becomes magnetic, and much more rapidly than the steel bar, but does not so long retain its magnetism. If a soft iron bar, held in this position, is struck a few times by a hammer, its magnetism, which was before temporary, becomes permanent. The blows of the hammer seem to impart in some mysterious way a coercitive force to the temporary magnet.

Large masses of iron, when kept in a stationary position for any length of time, always give proofs of having been magnetized by the earth. Tools in workshops are apt to become permanently magnetic from the repeated hammering to which they are subjected. The magnetism of the loadstone is due to the silent but continuous inductive action of the earth.*

Saturation Point of Magnetism.—The limit of the amount of magnetism that a magnet can permanently retain is called the point of satura-

* On this subject we may refer to the able pamphlet of Professor Mayer on "The Earth a Great Magnet."

tion. If any magnet receives more of magnetism than it can permanently retain, it gradually loses it or throws it off until it falls to the point of saturation, when it ceases to lose any more. The saturative point of any magnet depends on its temper and coercitive force.

Magnetism is very markedly influenced by temperature. When a magnet is heated it loses its magnetic power in proportion as its temperature rises; when it cools it regains more or less of what it has lost.

CHAPTER II.

FRICTIONAL, OR STATIC, OR FRANKLINIC ELECTRICITY.

When glass is rubbed with silk it acquires the power of attracting any light substance, such as a pith-ball. By a short contact this property is also communicated to the pith-ball, and it then repels the glass instead of being attracted.

These phenomena are explained by the existence of a force which is termed electricity. It was at one time believed that all friction of glass with other bodies produced vitreous or positive electricity, and all resinous substances resinous or negative electricity. This we know to be an error. Thus resins excited with cotton, flannel, or silk are negatively charged; while excited with sulphur or gun-cotton are positively charged. The conditions thus depend not only on the character of the body rubbed, but upon the material with which it is excited.

The name electricity is derived from the Greek word ἤλεκτρον, meaning amber, because, as the story goes, Thales of Miletus, one of the seven sages of Greece, first discovered the manifestations of this mysterious force by rubbing a piece of amber with a dry cloth.

The science of electricity dates from 1600, when Dr. Gilbert, of Colchester, physician to Queen Elizabeth, published a work on magnetism, entitled "Tractatus de Magnete." He first used the word electricity. He showed that not only amber, but other bodies, as sulphur, wax, etc., develop electricity. He first used the term poles in magnetism, and announced the first theory of terrestrial magnetism. Not only sealing-wax and glass, but all bodies contain more or less of electricity that may be thus developed by some kind of friction.

Conductors and Non-Conductors.—All bodies are electrically divided into three classes: Conductors, semi-conductors, and non-conductors. Under the first class—conductors—are included water and all saline solutions, the metals, the earths and stones, the structures of plants and animals, etc., etc. Under the second class—semi-conductors—are included ether, alcohol, dry wood, marble, paper, straw, etc., at 32° F. Under the third class—non-conductors, or insulators—are included glass, sealing-wax, porcelains, resins, sulphur, wax, dry metallic oxides, fatty oils, etc., at −13° F.; phosphorus, india-rubber, gutta-percha, collodion, wool, dry hair, silk, shellac, ebonite, amber, feathers, chalk, lime, dry gases, and aqueous vapor in a dry state.

The conducting power of metals may be lessened by heating them. In nearly all other substances heat increases the conducting power. Certain substances, such as feathers, wool, hair, and the atmosphere, which in a dry state are non-conductors, become conductors when thoroughly moistened.

In this classification of all substances into conductors, semi-conductors, and non-conductors, reference is had only to frictional electricity. Substances that are good conductors for frictional electricity are non-conductors for voltaic electricity.

Frictional electricity may be obtained not only by rubbing, but also by cleavage and pressure. When a piece of mica is cleaved, the two plates which are separated exhibit opposite electricities, and a faint light is observed when the cleavage is made in the dark. The light that is seen when sugar-candy or loaf-sugar is broken is accounted for by the development of electricity through cleavage.

When a thin piece of cork is pressed against a slice of orange, by insulating handles, one assumes a positive and the other a negative electricity. The same phenomena may be obtained by cleavage and pressure of very many other substances, and under diverse conditions.

A conductor is said to be insulated when it is placed on some non-conducting substance, so that the electricity communicated to it is prevented from passing into the ground. Glass is one of the best non-conductors, and is the insulating material usually employed in the construction of electrical apparatus. It is hard, durable, and easily obtained, and, could its surface be kept always dry, would be surpassed as an insulator by no material. In frosty and dry weather it acts very well; but when the atmosphere is at all damp, it becomes coated with a layer of moisture, which very much impairs its insulating power.

A much superior insulator to glass is ebonite, a preparation of vulcanized india-rubber that of late has been much used.

Electric Field.—If two surfaces oppositely charged are placed near one another they tend to move together, and the intervening space is thrown into a peculiar state of stress, as though the medium in between had been stretched. Invisible lines of electric force traverse the space between the positively and negatively electrified surfaces, and this space so filled with electric lines is called an electric field.

Discovery of Electric Conduction.—Electric conduction was discovered by Stephen Grey in 1729. He found that when a wire 700 feet long, and hung on loops of silk, was connected at one end with a glass tube, and the tube was rubbed, the other end of the wire was electrified and attracted light bodies. When wire loops were substituted for the silk loops, the electricity passed off through the wire. Hence originated the distinction between insulators and conductors.

Loss of Electricity.—All electrified bodies lose electricity more or less, however carefully they may be insulated. There are two reasons for this:

First. No insulators are perfect. The best insulators, as glass and rubber, conduct somewhat.

Secondly. The air is a conductor; its conductive capacity depends upon the amount of moisture in it.

In *vacuo*, also, electrified bodies lose their electricity more rapidly than in air, on account of the diminution of the pressure on the insulating surface.

The human body, as will be shown under Electro-Physiology, is charged with electricity, which is conducted away by the air, and not unlikely by other conductors.

Static Influence.—An insulated conductor, when charged with either positive or negative electricity, acts on bodies placed near to it just as the magnet acts on soft iron; it attracts the opposite and repels the same kind of electricity. This may be shown in the following manner: A brass cylinder (Fig. 5), rounded at either extremity, is insulated by means of a glass rod. Two pith-balls are suspended by cotton thread from each end. If an insulated ball charged with positive electricity be brought in close proximity to the brass cylinder, the pith-balls will diverge, showing a disturbance of the electric equilibrium in the cylinder. So soon as the charged ball is withdrawn, the pith-balls hang down as before, showing that the electric disturbance in the cylinder depended on the presence of the charged ball, and was merely temporary.

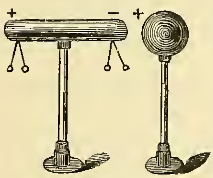

Fig. 5.

If a small disk of insulated gilt paper be brought in contact with the end of the cylinder next the charged ball, and then approached toward an electrometer, the needle will indicate that the disk has received – electricity.

If the experiment be tried with the opposite end, + electricity will be transmitted to the gilt disk.

It is thus seen that + electricity of the charged ball causes the near end of the cylinder to assume a – condition; while, according to a universal law, that no – electricity can be excited without an equal amount of positive electricity, the opposite extremity becomes +. The phenomenon thus described is called influence; and while in this peculiar electric condition the cylinder is said to be polarized.

Influence and Conduction Compared.—We have seen that a body may be charged with electricity both by conduction—actual contact—and by influence at a distance. In conduction the first body loses a part of its electricity; in influence it does not. In conduction the electricity given to the body is the same as that which gives it; in influence it is of the opposite kind. In order to impart electricity by conduction the body must be insulated; to impart electricity by influence, the body must be for the time in connection with the earth. Bad conductors are acted on by influence slowly, but retain their electricity longer; just as steel, which is slowly magnetized, becomes a permanent magnet, while soft iron, which is rapidly magnetized, soon loses its magnetism. There is a limit to the conductive capacity of every electrified body; when this limit is reached, it ceases to have any effect on the second body.

Distribution of Electricity.—It is evident that the greater the surface over which electricity is diffused the less is its power or intensity at any given point.

Electricity does not penetrate to the interior of metallic conductors, but diffuses itself over the surface.

Biot's experiment proves this. Let a copper ball be charged with electricity and suspended by a silk thread, and then covered with two hemispherical surfaces of brass which exactly fit it. When the hemispheres are withdrawn, it will be found that they are charged with electricity, which has been entirely taken from the brass ball.

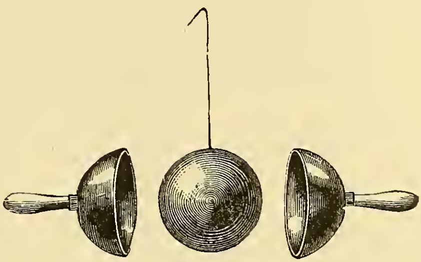

Fig. 6.

Faraday illustrated this truth by a beautiful and original experiment with a conical bag of cotton gauze, around the opening of which an insulated ring was attached. The bag was held distended by means of a silk thread attached to the apex, and then charged. By the proof-plane he found that the charge was wholly on the outside. The bag was then turned inside out by pulling the thread the other way, when it was found that the electricity had changed sides and lay wholly on the outside.

Density.—The quantity of electricity on a given surface at any moment is called electric density, or thickness.

The shape of a body has an influence in the distribution of electricity over it.

In an ellipsoid, for example, the density is greatest at the small end and least at the middle space.

On an insulated cylinder, with the two hemispheres at the ends, the density of the electricity is greatest at the ends. On a circular disk, the density is greatest at the edges. The tendency is for electricity to accumulate at points. On a sphere the density is uniform; the further removed a body is from a sphere the more irregular the distribution.

In all pointed rods the electricity accumulates at the pointed extremities; hence lightning rods are made to terminate at sharp points. In electro-physiology and electro-therapeutics it is found that small, pointed electrodes cause much more pain, the strength of the current being the same, than large, broad electrodes. Hence, except in those cases where it is desired to confine the action of the current to a very limited surface, electrodes of pretty good surface are desirable.

Electrophorus.—The electrophorus, invented by Volta in 1775, consists of a metallic mould, filled with a mixture of shellac and turpentine, and a movable metallic cover that is provided with a glass handle. The surface of the shellac is negatively electrified by beating it with a cat's fur or fox-tail. The cover is then put on, and by contact becomes negatively electrified, and gives to the finger a slight spark of negative electricity. If the cover be now removed by its insulating handle, it gives positive electricity to whatever touches it. This positive electricity it acquires not directly from the shellac, but by inductive action through the air.

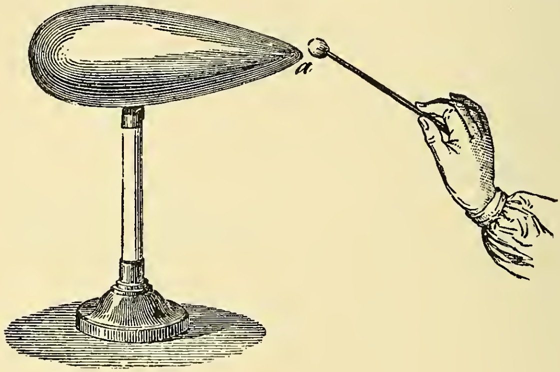

FIG. 7.

Electric Machines.—This term is exceedingly vague. It is applied to any and all forms of electrical apparatus. The first electric machine was made in 1672, by Otto von Guericke, of Magdeburg.* It consisted of a globe of sulphur, turned on its axis by one hand and pressed against the other hand. Afterward a glass cylinder was used instead of sulphur.

In 1740 Winckler substituted cushions of horsehair as rubbers. In 1760 Ramsden substituted a circular glass plate for the glass cylinder. The forms of electric machines now used are modifications of Ramsden's. This is one of the forms of apparatus from which we obtain static electricity. Fig. 8 represents the common cylinder electric machine, for developing electricity by friction.

Influence Machines.—These machines differ from that just described in that they depend upon the principle of influence and the principle of reciprocal accumulation. Let there be two insulated conductors (*A* and *B*, Fig. 9), electrified ever so little, one positively, the other negatively. Let a third insulated conductor (*C*), which will be called a carrier, be arranged

* "Experimenta Nova," Magdeburgica.

to move so that it first approaches A and then B, and so forth. If touched while under the influence of the small positive charge on A, it will acquire a small negative charge. Suppose that it then moves on and gives this negative charge to B. Then let it be touched while under the influence of

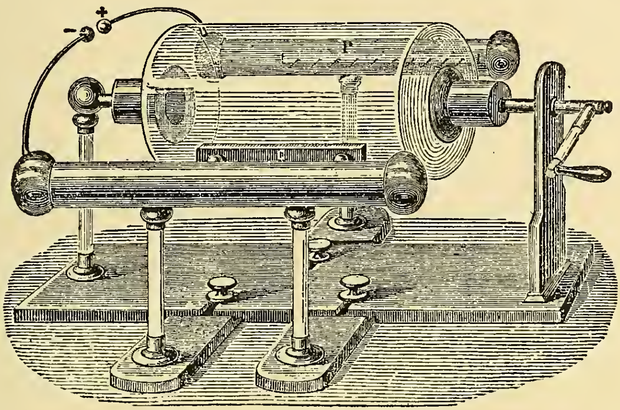

FIG. 8.

B, so acquiring a small positive charge. When it returns toward A, let it give up this positive charge to A, thereby increasing its positive charge. Then A will act more powerfully, and on repeating the former operations, both B and A will become more highly charged. Each accumulates the

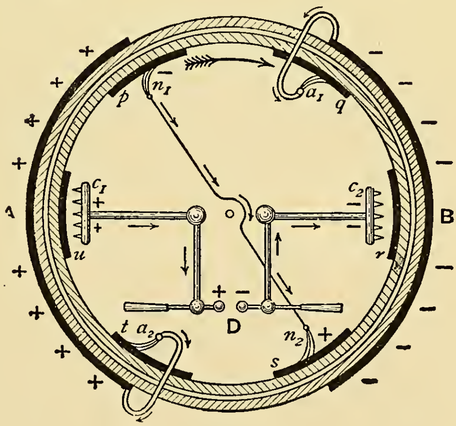

FIG. 9.

charges derived by influence from the other. This is the fundamental action of the machines in question. The modern influence machine dates from 1860, when C. F. Varley produced a form with six carriers mounted on a rotating disk of glass. This was followed in 1865 by the machine of Holt and that of Töpler, and in 1867 by those of Kelvin. Then followed the Wimshurst machines, perhaps the most widely used of all.

Wimshurst's Influence Machine.—We have in this machine no fixed field plates. In its simplest form it consists (Fig. 10) of two circular plates of varnished glass, which are geared to rotate in opposite directions.

What occurs in this machine is best explained by means of a diagram (Fig. 11). In order to render the explanation clearer, the rotating plates are represented as though they were two cylinders of glass, rotating in opposite ways, one inside the other. The inner cylinder will represent the front plate, the outer the back plate.

In Figs. 10 and 11 the front plate rotates right-handedly, the back plate left-handedly. The neutralizing brushes, n_1, n_2, touch the front sec-

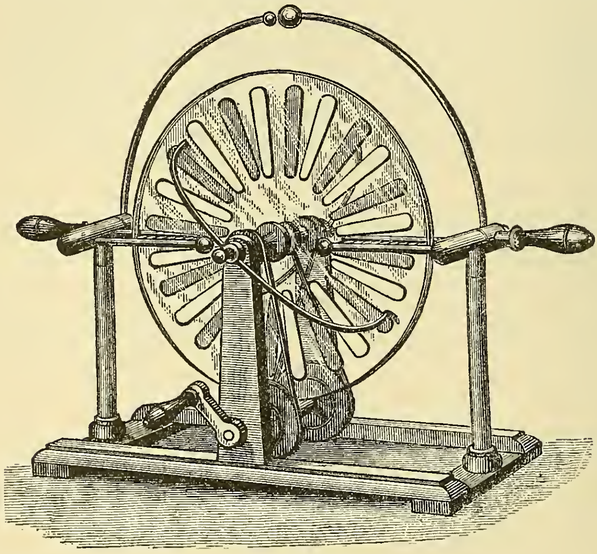

FIG. 10.

tors, while n_3, n_4 touch against the back sectors. Now suppose any one of the back sectors represented near the top of the diagram to receive a slight positive charge. As it moves onward toward the left it will come opposite the place where one of the front sectors is moving past the brush n_1. The result will be that the sector so touched while under influence by n_1 will acquire a slight negative charge, which it will carry onward toward the right. When this negatively charged front sector arrives at a point opposite n_3, it acts inductively on the back sector, which is being touched by n_3; hence this back sector will in turn acquire a positive charge, which it will carry over to the left. In this way all the sectors will become more and more highly charged, the front sectors carrying over negative charges from left to right, and the back sectors carrying over positive charges from right to left. At the lower half of the diagram a similar but inverse set of operations will be taking place. These and the other forms of influence machines are called rotation multipliers, because by their rotary motion they multiply by successive transmissions the charge of electricity that they communicate.

Electric Spark.—An interesting phenomenon connected with the electric machine is the electric spark which is drawn from the conductor when the finger is presented to it.

The positive electricity of the conductor decomposes the electricity of the body, attracting the negative and repelling the positive, and, when the tension is great enough, these opposite electricities overcome the resistance of the air and recombine with a spark and crackling sound. The

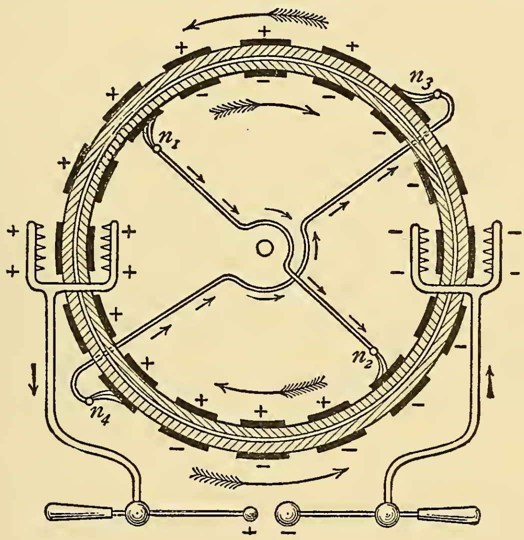

FIG. 11.

spark is accompanied by a prickly sensation. When the spark is short it is straight; beyond two or three inches in length it becomes curved or zigzag, like the lightning in the sky.

The human body may be charged with electricity by sitting on an insulated platform and touching the conductor of an electric machine.

When the body is thus charged, the hair diverges, a peculiar sensation is felt in the face, and if any other person standing on the ground touches one so charged he receives a spark, with a crackling sound and a prickling sensation.

Gold-Leaf Electroscope.—By this instrument we are enabled not only to detect the presence, but to determine the kind, of electricity that may exist in any body.

Fig. 12 represents Bennett's electroscope. *B* is a tubulated glass shade, enclosed at its lower end by a metallic cover, by means of which it communicates with the ground. A metal rod, fitting in the tubule of the shade, terminates at its upper extremity in a knob (*C*), and at its lower extremity it holds two narrow strips of gold leaf. On the inside of the shade are two strips of gold leaf reaching to the metal cover. If a body charged with either kind of electricity is brought in contact with the knob, the gold leaves diverge.

Thomson's Quadrant Electrometer.—This instrument is quite complex, but far superior for all delicate researches.

It is an electrometer in which the electrostatic charge is measured by the attractive force of plates or quadrants, on a light needle of aluminum suspended within them. The sectors or quadrants are of brass, and are

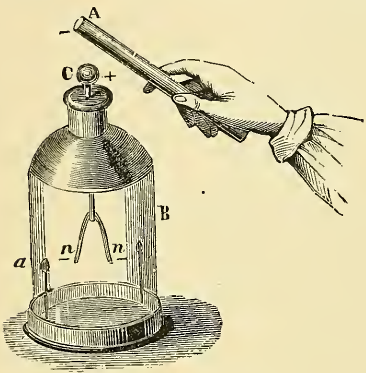

FIG. 12.

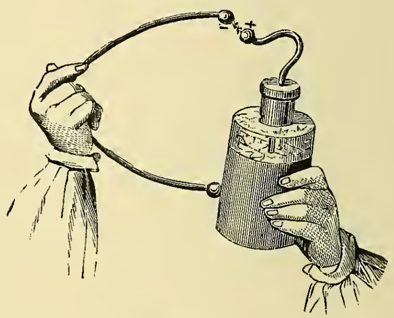

FIG. 13.

so shaped as to form a hollow cylindrical box when placed together. They are, however, insulated from one another; but the opposite ones are connected by a wire. The needle, which is maintained at some constant potential by connection with the inner coating of a Leyden jar, is generally suspended by two parallel silk threads, so that it freely swings inside the hollow box. To use the instrument, the sectors are connected with the source whose difference of potential is to be measured, and the deflection of the needle observed through a telescope by means of a beam of light reflected from a mirror attached to the upper part of the needle.

Leyden Jar.—The Leyden jar (Fig. 13) is made of glass, with a coating of tinfoil inside and out, extending to within a few inches of the mouth. Through a varnished wooden cover a wire, having a knob at top, is passed, and extends to the inside coating. Now, when either positive or negative electricity is communicated to the knob at the top, it is immediately diffused over the whole inside coating; and by its inductive influence the outside coating takes on the opposite kind.

When in this state—the two coatings being oppositely electrified—the jar is said to be charged; and a discharge takes place when a communication is established between the knob and the outside coating, the equilibrium being restored with a bright flash of light and a sharp report.

As the human system is a good conductor, this discharge may take place through it by grasping the outside coating with one hand and touching the knob at the top with the other; or several persons may form a line by grasping hands, the one at one extreme touching the outside coating, while the one at the other extreme touches the knob. All will feel the shock, as it is called, at the same instant. While the jar is receiving

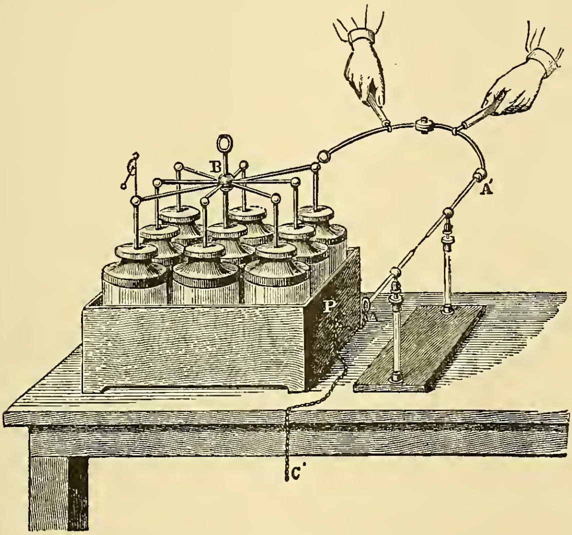

FIG. 14.

the charge, it must not be insulated—that is, the outside must communicate with the earth. As the positive charge collects on the inside, the outside becomes negative by the expulsion of the positive charge, and the accumulation of the negative charge in its stead, drawn from the earth. But if the outside is insulated, these transfers to and from it cannot take place, and therefore the jar cannot become charged.

A submarine cable is really a vast Leyden jar. The wire constitutes the interior coating, the water the exterior coating, and the gutta-percha the insulator between them. On this account the passage of an electric current through a submarine cable is greatly retarded.

If it is desired to accumulate a very great charge of electricity, a number of jars must be employed, all their inner coatings being connected together, and all their outer coatings being united. This arrangement is called a battery of Leyden jars, or Leyden battery (Fig. 14). As it has a large capacity, it will require a large quantity of electricity to charge it fully. When charged it produces very powerful effects; its spark will pierce glass readily, and every care must be taken to avoid a shock from it passing through the person. The "universal discharger" as employed with the Leyden battery is shown at the right of the figure.

History of the Leyden Jar.—In October, 1745, a bishop of Cammin, in Pomerania, Von Kleist by name, passed through a cork in the neck of a flask an iron nail connected with an electric machine. The flask contained mercury or alcohol. On touching the nail, Von Kleist received a severe shock. In January, 1746, Cuneus, Allamand, and Muschenbroek passed a wire from an electric machine into a flask filled with water. Muschenbroek held the flask in his right hand, and when a turn was given to the machine he received a spark from the conductor with his left hand.

The spark was so terrible that he declared he would not receive another like it for the French crown. He observed what Kleist did not, that only the person who held the jar received the shock. In this experiment the hand of the observer corresponded to the outer coating of the ordinary Leyden jar. He was the most scientific of the three Leyden philosophers who have given the name to the Leyden jar.

The theory of the Leyden jar, and apparatus similar to it, was given by Franklin in 1747. In the same year Watson, Bishop of Llandaff, sent a discharge from a Leyden jar through 2,800 feet, and subsequently through 10,600 feet of wire.

Experiments like these were also made by Franklin across the Schuylkill.

For a long time franklinic electricity was the only form used in electro-therapeutics.

Subsequently it was almost entirely superseded by faradic electricity, owing partly to the greater convenience and certainty of action of the latter. In recent years franklinic electricity has again come to the front. The construction of its apparatus has been greatly improved and new methods of its application have greatly widened the range of its usefulness.

In the chapter on "The Use of Franklinic Electricity," the subject will be found more fully considered.

CHAPTER III.

GALVANIC OR VOLTAIC ELECTRICITY.

Under the general term dynamic or current electricity is included the electricity which arises, first, from chemic action—especially from that attending the decomposition of metals—called galvanic or voltaic electricity; secondly, from induction by currents or magnets, called induced electricity, electro-magnetism, or magneto-electricity; thirdly, from heat, called thermo-electricity. These varieties are called dynamic electricity, signifying electricity in motion as distinguished from frictional or static electricity, which denotes the electric condition of bodies in which electricity remains insulated or stationary. Strictly speaking, these terms—dynamic and static—are applicable to both branches of the science; for if the poles of a series of galvanic batteries are insulated, they manifest, before the current begins, the electric tension of a friction machine. Again, the characteristics of the galvanic current are manifested slightly in the series of discharges which are transmitted in a wire connecting the prime conductor of a machine in action with the ground or other negative conductor. Alternate currents are produced by special alternate current dynamos or alternators, and will be again alluded to.

Nature and Definition of Force and its Relation to Matter.—Force is that which is manifested in any change of motion. Electric force is that force with which electricity tends to move matter, and must not be confused with electro-motive force or that which tends to move electricity. Force is itself a primary motion and cannot be defined. Matter is a collection of centres of forces called atoms. Molecules are collections of atoms. A molecule is the smallest particle into which a body can be divided without losing its identity.

The molecules of a gas are in rapid and continuous motion, and the relative velocities in different gases have been easily determined. These motions and velocities are the result of the forces of which matter consists. It must be similarly true of liquids and solids: force and motion are the bases of their constitution. Indeed, without force matter would not exist at all, for matter is simply an aggregation of centres of force.

Ponderable matter is a form of force which our senses recognize. Ether pervades all matter and all space, but it is not recognized by sense, and yet it is none the less a manifestation of centres of force.

Electricity Compared with Other Forces.—If force be added to matter the equilibrium of that point is disturbed, and the disturbance is propagated from molecule to molecule, through matter or ether, or both. Heat by conduction and mass motion are of matter only. Heat by radiation and light are of the ether only. Electricity is now believed to be identical with the luminiferous ether. That this must be so is a necessary result of the great discovery of Maxwell, that light itself is an electric phenomenon, and that the light waves are merely electric, or, as he puts it, electro-magnetic waves. Chemic action is a rearrangement of atoms. After this action the sum of the activities of the molecules of the resulting product is different from that which its factors previously had. This difference is force, and appears sometimes as light and under certain conditions as electricity, but it is rarely or never confined to one mode of manifestation. The condition for the generation of electricity by chemic action appears to be that this action takes place at the surface of a conductor through which a current (so called) can circulate. Since the current is made of motion of the molecules of the conductor through which it passes, and of the ether, the nature of the conductor must modify the current itself. It is known that the current through a telegraph wire 500 miles long meets the greater part of its resistance in the first 100 miles. The current is modified by the material and length and size of the wire.

The differential physiologic effects of induction coils of different lengths and fineness may thus be in part explained. These differential effects will be spoken of in the electro-therapeutic portion of this work.

The Chemistry of the Battery Not yet Exact.—Chemistry can never be an exact science until temperature, specific heat, and matter are all considered and justly estimated in all reactions. This has not yet been accomplished.

We are unable to state *a priori* what must be the electro-motive force of the different batteries in use, since that, as we have seen, depends on data hereafter to be determined. Frequently, however, we are able to state which of two reactions must evolve the greater force, and so, under like circumstances, the stronger electric current. This is done by inspection of the electro-chemical series of elements. That series, however, must vary with the temperature, so that it is no sure guide.

Office of the Water in the Battery.—The water used in all common batteries serves as a solvent of the salt formed in the reaction. When the water used becomes saturated by this salt the current stops, and it declines in power as the solution approaches saturation.

Office of the Metals in the Battery.—Of the two metals in any battery one only enters into the reaction. Zinc has generally filled that place in all the best-known batteries, because it is nearer the negative end of the electro-chemical series than any other common and convenient metal. Potassium or sodium would be the *beau ideal* of the negative metal, but they are not convenient or practicable. Any metal or conductor which is not acted on by the fluid in which it is immersed may occupy the other place in the couple.

All modern research tends toward the conclusion that the different forms of electricity which we variously distinguish as magnetism, franklinic and galvanic electricity, electro-magnetism, are but expressions of one force, which force is, as we have seen, but a mode of motion of the universal ether. Very recently a European physicist has estimated the electro-motive force of Holtz's machine, and has expressed it in a mathematical form, so that it may be compared with the ordinary galvanic batteries.

In the present chapter we shall speak of the form of electricity that is generated by chemic action—galvanic or voltaic electricity. Analogy and experience make it more than probable that all chemic action whatsoever is attended with the evolution of electricity; and reasoning still further we may believe that all molecular disturbance, however excited, must give rise to electric disturbance. The play and interplay of electric phenomena are incessant and infinite; electric force, like light and gravity, is everywhere being generated and everywhere acting. If we are unable to detect the electricity generated by chemic action only under certain conditions, or when generated in comparatively large quantities, it is because of the imperfections of our knowledge and the want of sufficient delicacy in our apparatus for collecting and measuring electricity.

As a matter of experience it is found that voltaic electricity is most conveniently generated by the reactions that take place between two materials and an electrolyte, and as a matter of convenience and economy zinc is the metal at the expense of which the electric force is evolved, the other material acting merely as a conductor; but the combinations that are actually employed by physicists are but a fraction of those that are possible and conceivable.

Every year new batteries and modifications of old batteries are devised, but all of them are based on the general principle that chemic action of any sort whatsoever is attended by the evolution of electricity.

We present below brief descriptions of some of the principal batteries that are now in use. All, or nearly all of them, in their original shape, or under various modifications, are used in electro-therapeutics. We shall not attempt to exhaust the list, but to illustrate those that are best known, most useful, and are most thoroughly representative. Those who understand the principle on which these batteries are constructed will not find it difficult to understand any new modification of them that may arise.

Here let us interpose the remark that the time and energy that are devoted to the study of the chemistry of batteries will not be wasted time—will indeed be spent most wisely—for half the annoyances of young and old electro-therapeutists comes from the difficulty of keeping their batteries in order. This difficulty will be diminished one-half and more when we really understand the mechanism of batteries and the laws that govern their action.

Simple Voltaic Cells.—In the formation of a simple voltaic cell there are usually metals and a liquid.

Fig. 15 constitutes such a cell.

Let C and Z represent respectively plates of copper and zinc introduced into dilute acid, and connected by a wire. Chemic action takes place over all the surface of the zinc covered by the liquid. Positive electricity is generated at the zinc element, and flows through the liquid to the copper, and thus a constant current is established over the wires, as shown by the arrows.

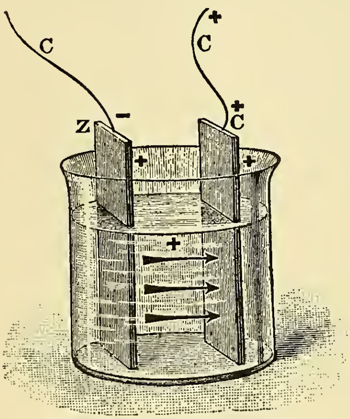

FIG. 15.

So far as the chemic action is concerned, it matters not whether the plates touch each other or are connected by wires, as in the figure. A current is formed, whether contact is made between the plates either above or below the liquid. In every instance, however, a circuit must be formed through which the electricity may traverse.

The electricity may traverse the circuit either in a single current or in a number of partial currents, into which it may divide itself when the plates are brought in contact along their whole surfaces. When the plates, or the wires which connect them, are in contact, the circuit is said to be closed; when they are separated, it is said to be broken or open. The electricity is generated wholly by the chemic action of the acid upon the zinc, and, other things being equal, the quantity of electricity set in motion will be proportional to the extent of zinc surface exposed to the acid.

The Terms Electro-Positive and Electro-Negative.—Both in simple and compound cells the electricity always moves in the liquid of the battery from the zinc to the copper; and out of the liquid from the copper to the zinc. In other words, the zinc is trying to dissolve and throw a current across to the copper; while the copper is trying (less powerfully) to dissolve and throw a current across the other way. This should be remembered, since the zinc is called the electro-positive element, although out of the liquid it is negative; and, consequently, in the decomposition that occurs in the battery, that element which goes to the zinc pole is called the electro-positive element, being attracted by its opposite force; while the element going to the copper is called for the same reason, the electro-negative—a current from one liquid and two metals.

Two liquids and one metal can also produce a circuit as well as one liquid and two metals. Becquerel's oxygen battery (*pile à oxygène*) is one of the best arrangements of this kind. The current is produced by the action of caustic potash on nitric acid, platinum forming the conducting arc.

Homogeneity of the Galvanic Circuit.—In frictional electricity there are points which form the seat of + or − electricity. On the contrary, in a wire where a galvanic current is circulating, there are no such points. It has no power, like frictional electricity, to attract or repel objects. The wire feels and behaves no differently when the current is passing than when it is not. The wire conducts so much better than the air that the current follows it. Its force is the same at every point, in the battery or in the circuit. Making interruptions in it at different points, and sending currents through solutions of sulphate of copper, the same amount of copper is deposited at each of the places where the interruption is made. If we connect the several breaks by pieces of platinum wire, each wire will be heated to the same temperature.

In short, the magnetic-heating and chemic and other effects of the current are the same at every point in the circuit.

Electric Relations of the Elements.—In the galvanic cell, by the decomposition of the water, oxygen arises at the positive pole and hydrogen at the negative.

The metals assume opposite electricities, the zinc being positive and the copper negative.

Since electricities that attract each other are opposite to each other, the substances that are liberated at the positive pole are called electro-negative, and the substances liberated at the negative pole are called electro-positive. Thus, in the decomposition of the battery, oxygen which is liberated at the zinc is electro-negative, while hydrogen which accumulates at the copper or platinum is electro-positive.

The elements have been arranged as to their electro-chemic relations when associated in pairs in the galvanic cell. According to recent chemistry, atoms are arranged in two classes, according to their combining power. Positive atoms are those which are attracted to the negative electrode in electrolysis, and whose hydrates are bases. Negative atoms are those that are attracted to the positive pole in electrolysis, and whose hydrates are acids. The electro-chemic series are presented below:

ELECTRO-CHEMIC SERIES.

Negative end −.	Silicon.	Zinc.
Oxygen.	Hydrogen.	Manganese.
Sulphur.	Gold.	Lanthanum.
Nitrogen.	Osmium.	Didymium.

Fluorine.	Iridium.	Cerium.
Chlorine.	Platinum.	Thorium.
Bromine.	Rhodium.	Zirconium.
Iodine.	Ruthenium.	Aluminum.
Selenium.	Palladium.	Erbium.
Phosphorus.	Mercury.	Yttrium.
Arsenic.	Silver.	Glucinum.
Chromium.	Copper.	Magnesium.
Vanadium.	Uranium.	Calcium.
Molybdenum.	Bismuth.	Strontium.
Tungsten.	Tin.	Barium.
Boron.	Indium.	Lithium.
Carbon.	Lead.	Sodium.
Antimony.	Cadmium.	Potassium.
Tellurium.	Thallium.	Rubidium.
Tantalum.	Cobalt.	Cæsium.
Columbium.	Nickel.	*Positive end* +.
Titanium.	Iron.	

Each atom of any of the substances in this list is positive to any atom of any substance above it, and negative to any one below it. These distinctions are therefore purely relative.

Thus, for example, copper, when associated in a galvanic pair in the proper fluid with any one of the elements below it, generates positive electricity and becomes electro-positive, but when associated with any one of the elements above it, becomes electro-negative.

The more electro-negative any one of the elements in this series is to a given element, the more intense will be the current generated when they are united in a galvanic pair. For example, the current generated by zinc and copper is feebler than that obtained from zinc and platinum, and the current is less when carbon is substituted for the platinum. The order in the above arrangement is, however, by no means absolute. The relative position of the metals depends frequently on the liquid in which they are immersed. Thus silver is − toward lead in a solution of dilute sulphuric acid, while in a solution of cyanide of potassium it is + toward it.

Amalgamation.—If pure zinc is immersed in dilute sulphuric acid no change is manifest, while ordinary commercial zinc is quickly decomposed by it. The action of the dilute acid on zinc is due to the impurities of iron or lead which it contains. These impurities are electro-negative toward zinc, and they cause local currents of electricity. When the battery is closed, these local currents interfere with the action that produces the main current; when the circuit is open, they may still keep up their action, as is evidenced by the bubbling up of the gases, and thus the zinc may be in time destroyed.

Now, local action in a single battery cell, arising from the above cause, not only consumes the power of that member, but reduces the energy of the whole series. In order to avoid this evil, resulting from local action, it is necessary that the zinc plates be amalgamated with mercury. The amalgamated surfaces are reduced to one uniform electric condition, like pure zinc, and will remain in the fluid a great length of time unacted on, until connected with the electro-negative element.

At the present time all improved batteries are constructed with amalgamated zinc.

How to Amalgamate Zinc.—To amalgamate zinc, first immerse it in a solution of dilute sulphuric acid of almost any strength, so as to clean the surface; then dip it in mercury, or pour mercury over it, and rub it on with a brush or sponge or cloth. The mercury will spread very rapidly over the surface of the zinc, and give it a bright, mercury-like appearance.

The art of amalgamating zinc is of great practical importance to the electro-therapeutist, since nearly all the batteries in common use have zinc for one of the metals. Amalgamated zinc was first used for galvanic batteries by Kemp, in 1826.

Chemic Action the Origin of the Current.—When the electrically opposite metals—zinc and platinum, for example—are dipped in acidulated water and united at their ends, either directly or by a wire, the zinc has so strong an attraction for the oxygen of the water that it unites with it and forms the oxide of zinc. This oxide of zinc combines with the sulphuric acid and forms sulphate of zinc. The hydrogen of the water escapes in the form of gas at the platinum. The result of this chemic action is a current of electricity. The zinc (the electro-negative element) is consumed, and the quantity of electricity generated is proportioned exactly to the quantity of zinc decomposed.

It had been supposed by Volta and his followers that simple contact of the metals was all that was necessary to excite the current; but Faraday showed, by two very beautiful experiments, that mere contact was not sufficient—that there must be chemic action in the cell in order to obtain a current. It is possible that all chemic actions are attended with the generation of electricity; but only under certain conditions, or when the amount is considerable, are we able to detect it.

In What Way does Chemic Action Generate the Current.—When the plates of zinc and platinum are immersed in a solution of dilute sulphuric acid, the zinc of ordinary commercial purity, and not connected outside by a conductor, the following occurs:

The sulphuric acid or hydrogen sulphate, H_2SO_4, is decomposed, zinc sulphate, $ZnSO_4$, is formed, and hydrogen, H_2, liberated. The hydrogen is liberated at the zinc plate. The solution becomes heated.

If, however, the plates are united by a conductor outside of the solution, the following change takes place:

The sulphuric acid is decomposed as before. The hydrogen is liberated at the platina plate only. The heat not only appears in the solution, but all parts of the circuit as well. An electric current is established throughout the entire circuit, and will continue so long as there remains sulphuric acid to be decomposed or zinc to form zinc sulphate.

Electricity a Mode of Motion.—Although, for the sake of convenience, we speak of electricity as a current flowing in certain directions, after the manner of a river, yet, as we have already said, we should not thereby be led into the error of supposing that the electricity is a real fluid flowing through different substances, or from one substance to another.

Electricity is a Disturbance Propagated in the Molecules of a Body, and at the same time in the Ether Pervading that Body.—The theory that light was caused by the emission of particles from the sun was abandoned long ago; and now the theory that light consists of undulations of ether is considered to be as impregnable as the theory of gravitation. Similarly we may believe that electricity consists of movements of a different kind from those of light, but which is variously modified in its manifestations by the substances through which it circulates.

The impulse or movement that constitutes what we call the current may be regarded as simply a mode of motion.

Polarity of Electricity.—Polarity, or properties in opposite directions, is not peculiar to electricity. Light and heat may also be polarized, and chemic attractions and repulsions are likewise manifestations of the polar qualities of atoms. We may gather a definite idea of the nature of electricity and the character of the so-called "current" by the following illustration: Let a tube be filled with balls, all of which are attracted to each other. If the first ball is turned round on its centre, it will turn in a similar way the next ball, and so on through the whole series. There is here no progress of a material current, but simply a motion.

If the motion is rapidly repeated through the attempt of electricity to find an equilibrium, we have what we call an electric current.

Electricity Convertible into the Other Great Forces.—We see in this section on electro-physics many illustrations of the transformation of one force into another. If we start with heat, we find that it produces electricity, and through electricity produces chemic action, magnetism, and light. If we start with magnetism, we find that it produces electricity, and through electricity heat, chemic action, and light. If we start with chemic action, we find that it produces heat, light, and electricity. If we start with electricity, we find that it produces magnetism, heat, light, chemic action, and motion.

Conversion of Electricity into Heat, Power, and Light.—Various kinds of work—chemic, magnetic, mechanic, and thermal—are done by electricity, and wherever work is done it is done by the expenditure of a part of the energy of the current. By the law of the correlation of forces the electricity generated in a battery may be converted into heat. This heat may remain in the battery or be transferred to any part of the circuit. In order to convert the electricity into heat it must pass through some poor conductor that resists its passage, and thus compels it to appear as heat. With ordinary thick copper wire there is but little sensible heat in the passage of a current, because copper wire is a good conductor; but when platinum wire, which is a poor conductor, is used, it is raised under a strong current to white-heat. This has been utilized in galvano-cautery.

Joule's Law of Development of Heat.—The principle is illustrated in Fig. 16. A glass vessel containing alcohol, into which also a thermometer dips, encloses a thin wire joined to two stout conductors. The relation

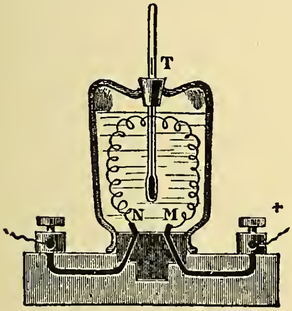

FIG. 16.

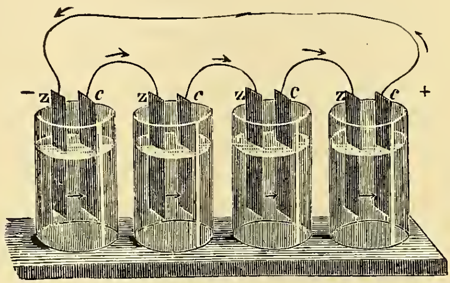

FIG. 17.

of the wire to other resistances is readily calculated if its own resistance is known. The following equation is the result of this calculation:

$$U = C^2Rt \times 0.24.$$

C indicates the current in amperes, R the resistance in ohms, t the time in seconds, and U the heat in calories; one calorie being the amount of heat that will raise 1 gm. of water through 1° C. of temperature. This equation is equivalent to the statement that a current of one ampere flowing through a resistance of one ohm developes therein 0.24 calories per second.

In the electric light the heat is transferred to carbon points interposed in the circuit. Particles of carbon become incandescent, and are volatilized and transported from the positive to the negative pole. A metal or other substance may give an electric light, but carbon, on account of its friability, gives a better and stronger light than any other substance. The electric light was invented by Sir Humphry Davy in 1813.

Compound Galvanic Cells.—The compound galvanic battery is composed of two or more simple galvanic cells. They are so connected together that the copper of one battery is joined to the zinc of the next, and so on throughout the series. By combining together a number of cups, such as are represented in Fig. 17, we form an excellent compound circuit. Each cup contains a zinc and a copper plate, which are connected together as described above. By examining this arrangement, it will be seen that one extreme of the series is copper and the other zinc. If these two extremes or poles are connected by a copper wire, the current will flow in the direction of the arrows, both through the series and over the wires.

Derived, or Shunt or Branch Currents.—When a current in its passage through any conductor meets with different qualities of resistance, it subdivides into various branch currents. In Fig. 18 the current goes from the elements through the wire *r*, *g*, *p*, *n*, *m*; but if a second wire *n*, *x*, *g* be interposed, the current will divide at *g*, *n*, part going by way of *g* and part around through *x*, *n*. The divided currents which go through the wires are called derived or shunt currents. If, instead of one or two wires, a large number were interposed, the current would subdivide itself as many times as there were wires, part going through each wire.

In thus dividing into derived or shunt currents, two laws are obeyed:

FIG. 18.

1. The sum of the strength of the divided current is equal to the strength of the principal current. If (in the figure) the strength of the current *g*, *p*, *n* is 40, and *g*, *x*, *n* is 60, then the strength of the principal current in *r*, *g*, before division, is 100.

2. The strength of the currents in the divided parts is inversely as the resistance in those parts. This law supplements the first. Resistance is directly as the length and inversely as the diameter.

If the derived wires are of the same length and diameter as the principal wire, then the current will divide into equal parts between them. If the derived wires are of the same length as the principal wire, but of unequal diameters, the current will divide unequally, according to the diameter of each wire. The law may be illustrated by thinking of the course that rivers pursue when they are subdivided or split up into deltas. The quantity of water that flows through all the subdivisions or deltas would be equal to the quantity that flowed through the main stream before the divisions took place. If the subdivisions are of different sizes, the deepest and widest will convey the most water.

When electricity passes through the human body it encounters tissues that differ considerably in their conductivity, and hence it subdivides into an infinite number of derived or shunt currents, the strength of which varies with the nature and length of the tissues. This point will be further illustrated in "Electro-Physiology and Electro-Therapeutics."

Description of Voltaic Batteries.—Under this head may properly be included, first, a description of the voltaic pile, which was constructed by Volta in 1799, and became known in England in 1800. The apparatus consists of a number of disks piled one above the other. The arrangement is in the following order: A disk of copper is placed on a frame of wood; a disk of cloth, moistened by acidulated water, is then placed on the copper, and then a disk of zinc on the cloth completes what is called the voltaic couple. A series of such couples constitutes a voltaic pile—the terminal copper being the positive and the terminal zinc the negative pole.

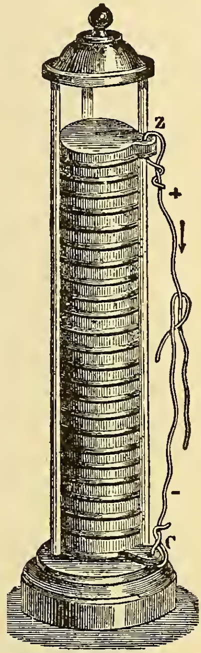

FIG. 19.

This apparatus is inconstant and unreliable, easily corrodes, has many inconveniences, and is now out of use. Various modifications of the voltaic pile have been devised, but all of them are too inconstant for electro-therapeutic purposes, or indeed for any sustained use whatsoever.

Polarization in Batteries.—When two metals, as zinc and platinum, are placed in acidulated water, the platinum plate becomes covered with a film of hydrogen. This hydrogen is electro-positive, like zinc, and so when the platinum becomes well covered we have electro-positive zinc opposed to electro-positive hydrogen, and thus the current becomes enfeebled, if not destroyed. This polarization in batteries is prevented in three ways:

1. *By Mechanical Depolarization.*—By keeping the liquids in constant agitation. Blowing into the liquid with a bellows, or stirring the liquid by any mechanical arrangement, keeps the surface of the platinum or carbon free from hydrogen, and thus prevents the weakening of the current.

On the same principle we explain the fact that lifting the metals out of the liquid for a moment or two at once increases the strength of the current. While in action, the hydrogen accumulates on the platinum; by removing the metals from the liquid an instant, the hydrogen escapes and the battery is as good as ever.

2. *By Chemic Depolarization.*—By this is meant the addition to the dilute acid or other excitant to dissolve the zinc some more powerful chemic agent as a depolarizer.

3. *By Electro-Chemic Depolarization.*—In a cell with two metals, each metal dipping into a solution of its own salt, the two solutions being kept apart by a porous partition, the electro-motive force does not change. The anode would not polarize when it dissolves into the excitant; the

cathode would not polarize since it receives merely an additional thickness of the same sort as itself. This principle of avoiding polarization is illustrated in the Daniell and other double-fluid cells.

Polarization of Electrodes and Currents of Polarization.—The electrodes that convey the current through acidulated water also become polarized.

Oxygen covers the positive and hydrogen the negative electrode. Hydrogen being electro-positive, and oxygen electro-negative, these two gases act like two metals, and if the current of the battery be broken and the two films of oxygen and hydrogen are connected metallically, an electric current is obtained, just as a current is obtained between zinc and platinum. In the liquid the current flows from the film of hydrogen to the film of oxygen. Two electrodes covered in this way with films of gas are called polarized, and the currents generated by these are called the currents of polarization. These currents of polarization are always in a direction opposite to the main current, and tend to interfere with and weaken it. This polarization of the electrodes takes place more or less in all applications of the galvanic current. One evidence of this is the discoloration of the electrodes that are employed in electrization after long use. To meet this difficulty unpolarizable electrodes have been devised. These will be described under "Electro-Therapeutics."

Accumulators or Secondary Piles.—If a series of plates of platinum, with moistened cloths between them, be connected with the poles of a battery, the gases (oxygen and hydrogen) resulting from the decomposition of the water accumulate in films on the platinum. If now the series be separated from the battery, it will itself, through the action between these films of gases, generate a current. A pile thus formed is called a secondary pile. It was discovered by Ritter. The accumulator devised by Gaston Plante (Fig. 20) consists of two pieces of sheet lead rolled up as electrodes, but without touching, and dipping into dilute sulphuric acid.

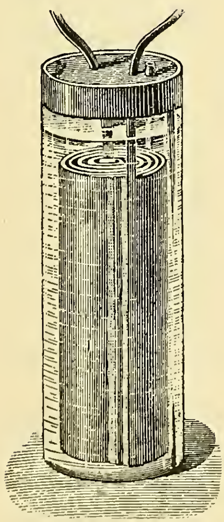

FIG. 20.

Gas Batteries.—The gas battery of Grove is constructed on the same principle. The gases are collected in glass tubes, oxygen in one and hydrogen in the other, and in each tube is fastened a platinum electrode. The tubes are inverted over sulphuric acid. When the electrodes are connected with a galvanometer a current is indicated, the direction of which is from oxygen to hydrogen.

There are two general varieties of batteries, double and single cell, but there are innumerable varieties of these, and only a few of the most important can be described.

Double-Cell Constant Batteries.—The current produced by elements with a single liquid becomes rapidly enfeebled, because of the polarization. This polarization is prevented in the double-cell batteries of Daniell, Grove, and Bunsen, by placing the electro-negative element in a liquid that is acted upon chemically by the deposited hydrogen. Currents from these double-cell batteries are called constant, because they do not weaken so rapidly as currents from single-cell batteries, and the metals can be allowed to stand all the time in the solution.

Daniell's Battery (Fig. 21).—The first constant battery was invented by Professor Daniell, of Edinburgh, in 1836. To prevent the evolution of hydrogen at the copper plate, it is immersed in a saturated solution of copper sulphate ($CuSO_4$). The nascent hydrogen then decomposes the $CuSO_4$, forming sulphuric acid (H_2SO_4) and a deposit of metallic copper on the copper plate.

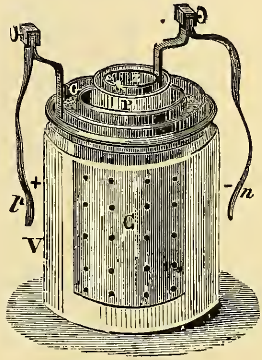

FIG. 21.

The construction is as follows: The more recent forms have a glass vessel into which is placed a cylinder of copper immersed in a saturated solution of copper sulphate. Inside of this copper cylinder a porous cup of unglazed earthenware containing a solution of zinc sulphate, into which is placed a zinc rod amalgamated. The copper cylinder is arranged at the top with a shelf, perforated, upon which are placed crystals of copper sulphate for the purpose of keeping the solution of copper salt saturated. A well-constructed and thoroughly prepared Daniell's battery will remain active for a long period of time.

Chemic Reactions in the Daniell Battery.—The arrow indicates the direction of the current, and the porous cup or partition by the double vertical lines.

With dilute zinc sulphate, the electrolytic circuit, prior to the first in the chemic reaction, is as follows:

$$\overbrace{Zn_x \mid ZnSO_4} \; \overbrace{ZnSO_4 \parallel CuSO_4} \; \overbrace{CuSO_4 \mid Cu_y}$$

$$\longrightarrow$$

After the first step:

$$Zn_{x-1} \mid ZnSO_4 \mid ZnSO_4 \parallel ZnSO_4 \mid CuSO_4 \mid Cu_{y+1}$$

The action taking place is a very simple one. There is a decrease of metallic zinc and increase of metallic copper. Zinc crowds copper out of the copper sulphate, so that there is a continuous change of $CuSO_4$ into $ZnSO_4$ by this process of replacement. The electro-motive force of a Daniell's battery as ordinarily set up is about 1.08 volts.

Grove's Battery.—This battery differs from Daniell's mainly in the substitution of a nitric-acid for a sulphate-of-copper solution, and platinum for copper, by which increased electro-motive force is obtained. In Fig. 22, A represents a glass vessel containing dilute sulphuric acid, Z a cylinder of zinc open at both ends, and V an unglazed earthenware vessel partially filled with nitric acid. P is a plate of platinum, with a cover, C, which rests on the porous vessel when the platinum is immersed in the nitric acid solution; *b* and *a* are binding-screws, which connect respectively with the platinum and zinc.

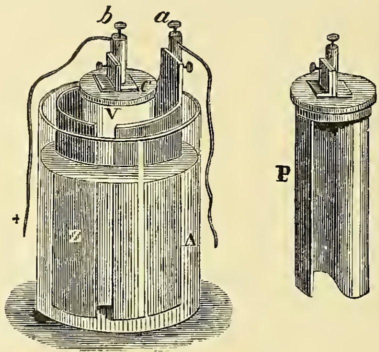

FIG. 22.

In this arrangement a double reaction occurs between the zinc, sulphuric acid, and nitric acid, giving as a result sulphate of zinc, water, and nitrogen dioxide, which is disengaged, and by contact with the air becomes nitrogen tetroxide. The reaction in Grove's nitric-acid battery is as follows: 1st, zinc; 2d, sulphuric acid; 3d, porous cup; 4th, nitric acid; 5th, platinum.

$$Zn_3 + (H_2SO_4)_3 + (HNO_3)_2 = (ZnSO_4)_3 + N_2O_2 + (H_2O)_4,$$

also $N_2O_2 + O_2 = N_2O_4$ by contact with the atmosphere. Force must be lost by the evolution of these nitrous fumes. Prof. Wolcott Gibbs, of Cambridge, has discovered that a small quantity of bichromate of potash in the nitric-acid cup of Grove's battery acts as a deodorizer by taking up the disagreeable nitrous-acid fumes. Thus one of the most serious objections to the use of this battery is removed. Grove's battery was invented in 1839.

Bunsen's Double-Fluid Nitric Acid Battery.—This battery is very similar to Grove's. It differs from it only in the substitution of carbon for platinum. The letter P in Fig. 23 represents a single element, as it appears when ready for use.

F is a vessel of glass containing dilute sulphuric acid. Z, a cylinder of amalgamated zinc. V, a porous vessel partly filled with ordinary nitric acid; and C, a bar of carbon or coke. The zinc is first placed in the vessel F, after which the porous vessel V, into the nitric-acid solution of which the carbon C has been immersed, is inserted into the zinc cylinder. The binding-screws *m* and *n* are respectively the positive and negative poles. The chemic action in the Bunsen battery is precisely the same as in the Grove. The hydrogen is intercepted by the nitric acid, and is thus prevented from reaching the carbon prism by oxidation.

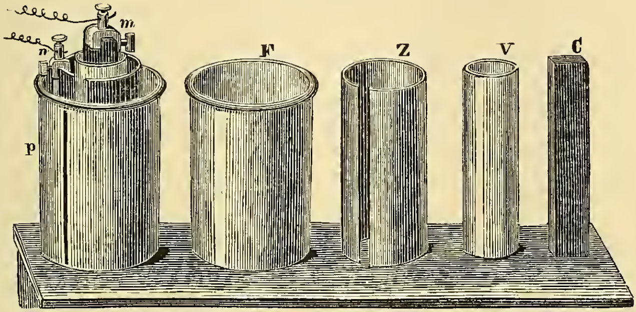

FIG. 23.

Bunsen's Bichromate Battery (invented in 1843).—In this battery a solution of bichromate of potash or sodium is used in the following proportions:

Bichromate of potassium or sodium	77 gm.
Sulphuric acid, commercial	78 c.c.
Water..	750 c.c.

Dissolve the bichromate into boiling water: when cold, slowly add the sulphuric acid. After all is thoroughly cold it is ready for use.

An ordinary Bunsen battery may be set up as follows: In the glass vessel place the amalgamated zinc cylinder, with a solution of dilute sulphuric acid. Place in the centre of the zinc the porous cup containing the bichromate solution and the carbon prism. Or since both solutions contain sulphuric acid, the porous cup can be dispensed with and both zinc and carbon immersed in the same fluid. In this latter case the zinc is usually placed between two plates of carbon, and insulated so as to prevent local action, also to reduce the internal resistance. The electro-motive force is about 1.9 volts.

The products of chemic reaction are chrome alum, sulphate of zinc, and water.

Walker's Zinc-Carbon Battery.—In this battery the same solution (electrolyte) is used, composed of bichromate of potash or sodium, sulphuric acid, and water, formula of which is same as for Bunsen bichromate battery.

While the action of the bichromate battery is such as to require some attention to keep in order, it is less objectionable than many.

Several modifications of this battery have largely entered into commercial use. Among others are the well-known types of Grenet, Plunge, Fuller, together with the great variety adapted for operating faradic coils, to say nothing of the portable galvanic apparatus. The products of chemic reaction in the various modifications are similar to the Bunsen bichromate battery.

It might be well, before proceeding further, to suggest the advantages of sodium bichromate over potassium bichromate. This has not been appreciated until quite recently:

1. It contains a larger percentage of available oxygen.

2. It is more soluble and dissolves in any quantity desired. A more dense solution can be used to advantage.

3. The battery does not require to be recharged so frequently.

4. The sodium bichromate solution is not so soon exhausted of useful oxygen, and will maintain a large current with a lower rate of loss.

5. The double sulphate of sodium and chromium, if they are formed at all, do not crystallize as in the case of potassium chrome alum, but remain in solution. The cells are therefore free from heavy crystalline formation and readily cleaned.

If the current falls, because of the exhaustion of the solution in direct contact with the plates, it may be increased by lifting the plates, agitating the fluid, or by carefully swinging the apparatus--to displace fluid, substituting new at the surface of plates. By adding to the formula for solution about three drachms of dissolved mercury (see previous directions for amalgamating fluid), the zincs will present a bright clean surface and local action will not take place so rapidly.

Never immerse the plates into a warm solution.

The carbons should be thoroughly baked and present a hard, firm appearance. Carbons that are poorly prepared contain impurities or are soft, will rapidly absorb the solution, corrode the contacts, and not only cause short circuits, but by corrosion of contacts become detached. The zinc plates should always be kept well amalgamated and the parts thoroughly cleaned.

We speak thus particularly of the simple zinc-carbon battery, because it is one very widely used in electro-therapeutics. and it is important that its management should be well understood. The galvanic batteries for medical use are mostly of single-cell zinc-carbon elements. The zinc-carbon battery, like Smee's, to be hereafter described, is not constant. If the metals are kept long immersed in the solution, the power rapidly goes down. It is necessary, therefore, to keep the elements out of the solution, except when the battery is in use. In this respect the battery differs very much from the batteries of Grove, Bunsen, and Leclanché, where the elements are never removed from the solution except to be cleaned and repaired.

Smee's Battery.—This battery (Fig. 24), invented in 1840, is very economical, convenient, and easy to manage, and on that account has been considerably employed to operate electro-magnetic apparatus. It consists of a plate of corrugated platinum, or silver covered with finely divided platinum, between the two plates of zinc, in a solution of sulphuric acid and water (one part to ten or twelve).

The order of the parts in Smee's sulphuric acid battery is as follows: 1st, Zinc; 2d, sulphuric acid; 3d, platinum.

Reaction.

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

The chemic action of this battery is more rapid than that of the sulphate of copper battery, because platinum is more positive than copper, whose place it occupies in the sulphate of copper battery. The disengagement of the hydrogen is effected by mechanical means, but there must be a large loss of force in changing hydrogen to a gaseous state, precisely as force is lost in changing water to steam.

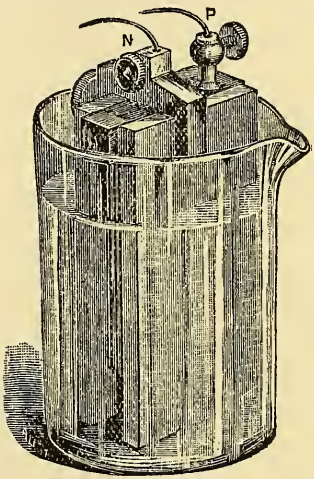

FIG. 24.

The object of corrugating the platinum plate, or making it into folds or furrows, is to give greater surface. The object in covering it with finely divided platinum is to roughen the surface so that the hydrogen will not adhere. It is customary in using the battery to keep about half a tablespoonful of mercury in the bottom of the cup, in order that the zincs may be all the time well amalgamated. Care should be taken, in the preparation of this battery, to prevent the mercury from collecting on the platinum plate. If by any carelessness it does get on the platinum plate, it will turn it to the color of mercury, and will weaken or destroy the force of the battery. In this battery slight action goes on even when the connections are not made; this is evidenced by the formation of sulphate of zinc at the top of the metals after they have been long immersed. It is therefore an advantage in using the battery to keep the elements out of the solution when not needed. In some modifications of this form of battery, such as the hydrostat tip, as made by Kidder Manufacturing Company, all the plates are removed from the solution by giving the jar a quarter turn.

If a little care is exercised with the battery, and by keeping the top part of the plates coated with beeswax or shellac varnish, the salts cannot accumulate to form connection between the platina and zinc plates, thus consuming the power of the solution.

Leclanché's Battery.—During the past few years this battery has attracted great attention both among telegraphists and electro-therapeutists. The great advantage that is claimed for it, where it is not used too long at a time, is that it is far more constant than any other battery yet invented. The battery was devised by Leclanché, a Frenchman, in 1868, and bears his name. A Leclanché cell consists of: (1) a rod of zinc in a concentrated solution of chloride of ammonium; (2) a plate of carbon, packed with powdered carbon and native peroxide of manganese in a porous cell. The chemic changes that take place in a Leclanché battery are these: Chloride of ammonium is decomposed, chlorine combining with the zinc, hydrogen being absorbed by the oxygen of the peroxide of manganese, and ammonia being liberated. The ammonia is absorbed by the water, but in process of time the water becomes saturated, then the ammonia escapes through the various openings.

The chemic formula is as follows:

$$Zn + (Cl\,NH_4)_2 + (MnO_2)_2 = ZnCl_2 + H_2O + (NH_3)_2 + Mn_2O_3.$$

Leclanché's battery was first arranged for electro-therapeutics by Gaiffé, an instrument-maker of Paris. It has been modified by Tripier, the well-known French electro-therapeutist, by Keyser and Schmidt, of Berlin, and a portable form has been devised by Beetz, of Munich. Le-

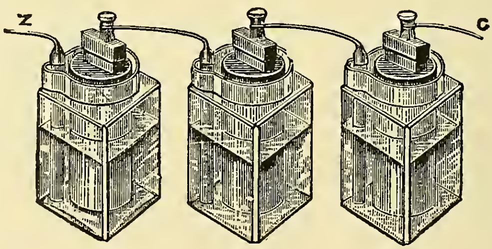

FIG. 25.

clanché's battery has one great advantage and some disadvantages. Its advantage lies in its power of endurance. If not overworked it will stand for months and years, and yet retain sufficient power to be quite useful in electro-therapeutics. This is not true of any other battery; even Daniell's, the most constant of all, and as variously modified, requires replenishing or cleaning every few months, else it goes down to nothing.

In Fig. 25 three Leclanché cells are shown joined in series. The "Axo," "Gonda," Law, Sampson, and others are modified forms of the Leclanché.

The Chloride of Silver Cell.—Chloride of silver as a depolarizer was first suggested by Marié Davy.

The elements in the cell are zinc and silver chloride, which through the nascent hydrogen becomes metallic silver. This battery does not readily polarize, and is much used for induction coils as well as to generate the direct current for therapeutic purposes.

Gravity Cells.—A modification of the Daniell cell already described is the gravity cell, in which, instead of employing a porous cell to keep the two liquids separate, it is possible, where one of the liquids is heavier than the other, to arrange that the heavier liquid shall form a stratum at the bottom of the cell, the lighter floating upon it. It is a cheap cell and simply constructed, but the heavy liquid gradually mingles with the lighter, so that the separation is not perfect.

Statistics of Cells.—The electro-motive forces of the batteries described, as well as a number of others, are given in the following table:

Name.	Anode.	Excitant (Solution of).	Depolarizer.	Kathode.	Approximate volts.
Volta (Wollaston, etc.)	Zinc	H_2SO_4	None	Copper	1.0 to 0.5
Smee	Zinc	H_2SO_4	None	Platinized silver	1.0 to 0.5
Law	Zinc	H_2SO_4	None	Carbon	1.0 to 0.5
Poggendorff (Grenet, Fuller, etc.)	Zinc	H_2SO_4	$K_2Cr_2O_7$	Carbon	2.1
Grove	Zinc	H_2SO_4	HNO_3	Platinum	1.9
Bunsen	Zinc	H_2SO_4	HNO_3	Carbon	1.9
Leclanché	Zinc	NH_4Cl	MnO_2	Carbon	1.4
Lalande	Zinc	KHO	CuO	Carbon	0.8
Upward	Zinc	$ZnCl_2$	Cl	Carbon	2.0
Fitch	Zinc	NH_4Cl	$KClO_3+NaClO_3$	Carbon	1.1
Papst	Iron	Fe_2Cl_6	Fe_2Cl_6	Carbon	0.4
Obach (dry)	Zinc	NH_4Cl in $CaSO_4$	MnO_2	Carbon	1.46
Daniell (Meidinger, Minotto, etc.)	Zinc	$ZnSO_4$	$CuSO_4$	Copper	1.07
De la Rue	Zinc	$ZnCl_3$	Agcl	Silver	1.42
Marié Davy	Zinc	$ZnSO_4$	Hg_2SO_4	Carbon	1.4
Clark (Standard)	Zinc	$ZnSO_4$	Hg_2SO_4	Mercury	1.434
Weston	Cadmium	$CdSO_4$	Hg_2SO_4	Mercury	1.025
Von Helmholtz	Zinc	$ZnCl_2$	Hg_2Cl_2	Mercury	1.0
Walker	Zinc	H_2SO_4	None	Carbon	.65
Callan	Zinc	$H_2SO_4HNO_3$	None	Iron	1.7
Becquerel	Zinc	$ZnSO_4$	None	Lead	.55
Niaudet	Zinc	NaCl	None	Carbon	1.65
Duchemin	Platinum	H_2SO_4	None	Lead	1.79
Howell	Zinc	$(NH_4)_2SO_4$	None	Carbon	2.04
Gordon-Burnham	Zinc	....	None	Copper	
Accumulators. (Planté, Faure, etc.)	Lead	H_2SO_2	PbO_2	Lead	2.1 to 1.85

Before closing the chapter on "voltaic batteries," we desire to call attention to a new battery—"the Gordon-Burnham battery" (Fig. 26). It is well adapted for the illumination of examination lamps, minor cautery work, and operating motors. It is of the zinc and oxide of copper type, greatly improved, and develops a large amount of energy. The electromotive force is about one volt. Internal resistance .04 of an ohm, or practically *nil.* It operates equally as well on closed or open circuits.

FIG. 26.

The points of superiority as determined by careful tests and practical demonstrations are: Long life, discharging at a rate of eight centiamperes for six months without any attention; efficiency, free from local action; no gases or odors, and maximum energy.

Instruments for Measuring Electricity.—The instruments for measuring electricity are quite numerous, and some of them are very delicate. It is necessary here to describe only a sufficient number to illustrate the principles involved.

Galvanometers.—A galvanometer is an instrument for indicating the presence and direction of a current, and for measuring its strength. There are several varieties of galvanometers, but all are constructed on the same general principle—a magnet freely hung so as to be deflected by the passage of a current through a coil of insulated wire. There are various types, known as absolute, astatic, ballistic, dead beat, differential, sine, tangent, torsion, etc.

Astatic Galvanometer.—This form of galvanometer is used either to detect the simple presence of a current, or to measure the strength of a weak current. Let A and B (Fig. 27) represent two needles of about equal strength, having the same axis and having their poles reversed in reference to each other. The needles will settle a very little in the meridian, from the fact that one of them is very slightly more highly magnetized than the other.

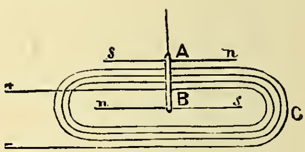

FIG. 27.

C is an insulated wire, bent around the lower needle several times. When a current is passed through this wire, the needles will be influenced to turn in the same direction. In this way the passage of the most feeble current may be detected. In connection with a thermo-electric pile, this instrument is capable of indicating a change of temperature of only a very small fraction of a degree. Galvanometers which have a long resistance coil, and in which a branch resistance coil, or "shunt," as it is called, is interposed, may be used to measure strong currents (see chapter on Ohm's Law), and are therefore convenient in comparing batteries.

Thomson's Reflecting Galvanometer.—Sir William Thomson has done much to advance the science of electrology by the construction of his reflecting or mirror galvanometer, which will indicate the presence of very slight currents. This instrument consists of the coils of a galvanometer, between which are suspended, by an unspun silk fibre, a mirror and magnet, which, when it moves under the influence of a current, is reflected through a lens on a graduated scale placed at a little distance in front of it. A lamp is placed behind the screen, which contains a slit, through which the light passes to the mirror, from which it is reflected back on the graduated scale. When the magnet is deflected by the passage of a current through the coil, the beam of light moves to the right or left along the scale, the angle made by the reflected light being twice the angle through which the mirror and magnet are deflected. A very small deflection of the magnet produces a very great displacement of the reflected light on the screen, and thus a very slight current can be detected.

The above class of instruments do not read direct units.

Galvanometers of improved types, and arranged for reading direct units for the commercial measurements of currents, are of many forms. They are exceedingly delicate, and each instrument must be carefully calibrated and its scale of reading made especially for its condition. A true instrument cannot be made by attaching a printed or previously prepared scale. They are generally constructed to read off, direct, volts, amperes, milliamperes, etc., and known as voltmeters, amperemeters, or ammeters, and milliamperemeters or milammeters.

For a more detailed description, reference should be had to standard electric works.

Rheostats: Instruments for Measuring Resistance.—The rheostat, an instrument invented by Wheatstone, was originally designed to ascertain the relative amount of resistance of different conductors. In electro-therapeutics it is employed to interpose resistances in the circuit, etc., so as to delicately modify the strength of the current within small fractions.

In electro-physiologic investigations, as also in certain branches of electro-therapeutics—particularly in applications to the ear—rheostats have been used. The more modern forms will be described in Electro-Therapeutics.

Early History of Galvanism.—In the year 1786, while Galvani, professor at Bologna, was experimenting with an old-fashioned electric machine that lay near a dish of frogs that had been prepared, it is stated, for his sick wife, he noticed that the frogs jumped whenever a spark was drawn from the conductor of the machine. On observing this, it occurred to him that perhaps he had found a means of detecting atmospheric electricity more delicate than he had previously employed. In order to test this, Galvani took the dish of frogs, and, with his neighbor Camillo, went out on the terrace of his house.* It was a clear evening in the early part

* At No. 96, in Strado S. Felice, Bologna, the house where Galvani lived, with terrace and railings, is still shown to travellers.

of September, and no marked electric phenomena were apparent in the air. Fixing an iron hook in the spine of each frog, he suspended it from the iron railing.

Behold, spontaneous movements appeared in the frogs, various in their character and quite frequent!

That moment was the birth of the science of galvanism. At once there flashed on the mind of Galvani the query, What causes these contractions? There were no electric disturbances in the air; the electric machine was far away inside the house. Could there be electricity in the frogs themselves? In the history of science it often happens that a theory partly false guides us into facts that are wholly true. Thus it happened to Galvani.

From that moment until he died he lived in an atmosphere of experiment.

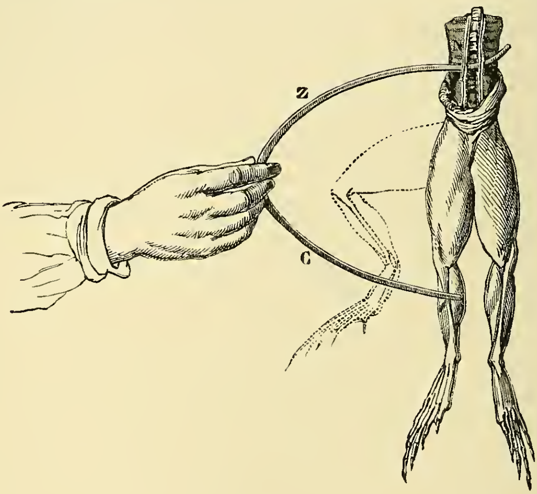

FIG. 28.

Frogs without number were slaughtered, and all for the purpose of proving to himself and others that it was animal electricity that caused these contractions.

Galvani's researches, as soon as they were made public, in 1791, excited great interest among scientific men, and inspired him to make another attempt to master the mysteries of electricity. At the time when Galvani made his discovery, the interest excited by the discovery of the Leyden jar and Franklin's kite, about forty years previously, had died out. Philosophers had followed the vein thus opened about as far as it seemed to lead. They supposed that the battles of electricity were all fought out, and so they were laying aside their armor. On the announcement of Galvani's discovery, his experiments were repeated all over Europe, and the theory that the contractions of the muscles of the frog were due to animal electricity was universally adopted.

Volta's Researches: The Theory of Contact and Chemic Action.—Among those who were stimulated by the discovery of Galvani was Volta, professor of physics in Pavia, Italy, who had already been long distinguished as an electric experimenter, and who, in the knowledge of this special branch, was far superior to Galvani.

At first Volta accepted Galvani's theory of animal electricity, but subsequent research caused him to doubt its truth. He observed that it was only by means of heterogeneous metals that muscular contractions could invariably be produced, and hence he denied the existence of animal electricity, explaining the phenomenon of muscular contractions through the influence of the artificial electricity excited by a heterogeneous metallic combination.*

Galvani then not only demonstrated that contractions could readily be caused by exactly homogeneous metals, but that the phenomenon was produced by the simple contact of nerve and muscle. His manner of experimenting was as follows: The leg of a frog, denuded of its skin, had its sciatic nerves cut at their exit from the vertebral column. The nerves thus denuded were taken gently up by some non-conductor and made to touch one of the muscles, when the leg would immediately become convulsed. Volta endeavored to prove that the concussion caused by the contact of nerve and muscle was the cause of the electric current thus produced; but Galvani conclusively demonstrated that such could not be the case, by placing a non-conductor between the two tissues, when no action could be excited in the leg. He went further, and at last succeeded in producing muscular contractions when only the nerves of non-prepared legs were brought in contact.

The discovery of the voltaic pile, which excited great interest in men of science, seemed to decide the battle for Volta, and all the efforts of Galvani to convince philosophers of the existence of animal electricity were in vain. Galvani's first observations on frogs date back as far as 1780. He first published his researches in 1791.

Volta did not undertake the investigation of the subject until 1792, the year following the publication of the researches of Galvani. And yet Volta has almost equal claim to be the founder of the science of galvanism; for while Galvani discovered the new manifestation of electricity, he failed to comprehend its true value, while Volta, by the discovery of the pile which bears his name, demonstrated what Galvani would never believe, but which Professor Fabroni, of Florence, had in 1792 suggested, that chemic action was the source of the electricity in Galvani's experiments.

* The theory that the experiment of Galvani could be explained by chemic action was first suggested by Professor Fabroni, of Florence, in 1792.

CHAPTER IV.

ELECTROLYSIS (ELECTRO-CHEMISTRY).

Electrolysis, derived from ἤλεκτρον and λύω, through λύσις, disengaging, is the act or process of decomposing a compound substance by electricity.

Electro-chemic decomposition takes place at both poles, but with different products and manifestations, according to the strength of the current, the nature of the substances acted upon, and the material of which the electrodes are composed.

History of Electrolysis.—The chemic effects of static electricity were first investigated by Drs. Priestley and Cavendish, in 1784. The decomposition of water by passing through it a succession of discharges of static electricity was first discovered, in 1789, by Messrs. Dieman, Paetz, Van Troostwyck, and Cuthbertson. The power of the galvanic current to decompose water was discovered and first described by Messrs. Nicholson and Carlisle, in 1800. They experimented with the voltaic pile, which had then just been discovered. These experimenters also decomposed other substances by the galvanic current. On November 20th, 1806, Sir Humphry Davy presented to the Royal Society a lecture "On some Chemic Agencies of Electricity," and in the following year he announced his discovery of the decomposition of the fixed alkalies. Between 1831 and 1840 Faraday published his "Experimental Researches in Electricity," in one of the most remarkable series of scientific essays that ever proceeded from the pen of man.

Terminology of Electrolysis.—With the aid of two friends, Faraday prepared the following terminology of electrolysis, which is now generally adopted. The poles where the electricity passes in and out of the body that is undergoing decomposition are called electrodes (electro, and Gr., *hodos*, way). The surface where the current enters the decomposing body is called the anode (Gr., *anodos*, way up, < *ana*, up, and *hodos*, way); the surface where the current leaves the decomposing body is called the kathode (Gr., *kathodos*, going down, < *kata*, down, and *hodos*, way). The anode is in contact with the positive pole and the kathode with the negative.

Practically, anode is used as synonymous with positive pole, and kathode with negative, although, strictly speaking, anode and kathode refer to the points of the decomposing body, and positive and negative to the poles of the battery that are in contact with these.

Compound substances that are directly decomposable by the current are called electrolytes (ηλεκτρον, and λύω, decompose). To electrolyze a body is to chemically decompose it by the current. The act of producing electrolysis is called electrolyzation.

The elements of an electrolyte are termed ions (εἰὼν, participle of the verb εἶμι, to go). These ions that appear at the anode are termed anions, those which appear at the kathode are termed kations. Formerly anions were termed electro-negative, and kations the electro-positive elements of the compound. Water, for example, is an electrolyte that evolves two ions—oxygen and hydrogen; oxygen goes to the anode and is the anion; hydrogen goes to the kathode and is the kation.

No substance can be an electrolyte which is not a conductor; but in the readiness with which they are decomposed substances widely vary. Every electrolyte must contain more or less of water. Pure water, though an electrolyte, is yet decomposed only with great difficulty; but by adding to it a little sulphuric acid, or certain salts, it very easily undergoes electrolysis. It is furthermore believed that no fluid can be a conductor without also being an electrolyte; that is, more or less electro-chemic decomposition must take place when the galvanic current passes through any fluid. Substances that are found to be ready electrolytes are chloride of sodium, muriatic acid, and iodide of potassium.

Laws of Electrolysis.—Although electrolysis, like all other phenomena connected with atomic changes, is but imperfectly understood, yet some of the general laws of its operations have been already well ascertained.

Among the more important of these laws the following may be enumerated:

1. *Definite Electro-Chemic Action.*—It has been found that when several substances are simultaneously decomposed by the current, the elements that are evolved are definite in quantity and are electro-chemic equivalents of each other. This law, which was discovered by Faraday, may be thus illustrated: Let the current be sent successively through a series of cells filled with oxide of lead, chloride of lead, and chloride of silver. The different substances would combine in the following proportions:

	At the Positive Pole.	At the Negative Pole.
Water..................	8 grs. oxygen.	1 gr. hydrogen.
Oxide of lead.........	8 " "	113.5 grs. lead.
Chloride of lead........	35.5 " chlorine.	103.5 " "
Iodide of lead..........	127 " iodine.	103.5 " "
Chloride of silver	35.5 " chlorine.	108 " silver.

These numbers, it will be seen, represent the combining proportions of these substances.

Substances combine in equivalent proportions; they are decomposed in the same equivalent proportions.

2. *Primary and Secondary Results.*—The results of electrolytic action are distinguished as primary and secondary. The results are called primary when the elements that are decomposed appear at the electrodes unchanged and uncombined; the results are called secondary when the elements that are decomposed are changed or recombined when they appear at the electrodes. The secondary results are favored by the nascent condition of the elements that are decomposed. The secondary results are caused by the action of the decomposed elements on the substance of the electrode, or on the substance itself that is undergoing decomposition. Even the decomposition of water, when diluted with sulphuric acid, is really a secondary result. Perfectly pure distilled water does not perceptibly decompose even under quite a strong urrent. If a few drops of sulphuric gases are added, the acids are freely disengaged. The sulphuric acid H_2SO_4 is disengaged by the current into H_2 at the negative and SO_4 at the positive pole; the former H_2 is liberated, and the latter SO_4 at the positive pole acts on the water and forms sulphuric acid again. Secondary decomposition is modified by the material of which each electrode is composed. Thus in decomposing sulphuric acid, when the positive electrode is made of carbon, the oxygen decomposed acts on the carbon, forming carbonic acid and carbonic oxide. Electro-chemic action continued for weeks, months, and years, as was done by that very laborious experimenter, Mr. Crosse, of Broomfield, may produce as secondary results interesting minerals, such as quartz, arragonite, malachite. During these experiments in electro-crystallization Mr. Crosse discovered that remarkable insect, the acarus, which appeared in electrized solutions of sulphate of iron, sulphate of zinc, and nitrate and sulphate of copper. It was supposed that the acari arose from ova deposited by insects floating in the atmosphere, and that they might possibly be hatched by electric action. As a reward for this discovery, which now seems to be almost forgotten, Mr. Crosse was subjected to absurd and outrageous abuse, as though he were infringing on the prerogatives of the Creator. Mr. Weekes, of Sandwich, in Kent, subsequently repeated the experiments of Crosse by passing electric currents through silicate of potash in glass receivers over mercury. All possible care was taken to keep out foreign matter. After a constant action of a year, insects appeared, entirely similar to those obtained by Mr. Crosse. The metallic deposits in electro-metallurgy are the secondary results of the electro-chemic decomposition. Water is electrolyzed, hydrogen is disengaged at the kathode, and oxygen at the anode; but the hydrogen reacts on the metallic solution, combines with its oxygen, and frees the metal. The oxygen also combines with an element at the anode. In the section on Electro-Surgery it will be found that the secondary decomposition is utilized in the selection of the material used for needles in galvano-puncture.

3. *The Differential Action of the Poles.*—Different elements go to the

anode and the kathode, according to the nature of the substance decomposed and the material of which the electrode is made.

Platinum wire makes the best electrode for electrolytic experiments on various substances, because platinum is not acted on. Copper and silver wire may be used, but the secondary action which they cause greatly complicates the experiment.

To distinguish the precise character of the changes that take place in the electrolysis of many substances is frequently difficult, and sometimes impossible. It is difficult to decide whether any of the elements of the electrolyte, besides water, undergo decomposition; and whether the changes are of a primary or secondary character.

Among the substances that are most readily decomposed by the electric current are the following:

Iodide of Potassium.—This decomposes under a very feeble current, the iodine and oxygen going to the positive and the hydrogen and alkali to the negative. Thus the decomposition of iodide of potassium by electricity affords a very good means of distinguishing the poles. The brown color of the iodine always appears at the positive pole. The whole solution soon presents the color of iodine.

Chloride of Sodium.—A solution of common salt decomposes quite readily, chlorine appearing at the positive and hydrogen and oxide of sodium at the negative pole. If the positive needle is platinum, the odor of chlorine is at once detected; if it is of copper, the chlorine unites with the copper, making the solution turbid.

Acetate of Lead.—This salt in solution decomposes with comparative slowness by secondary action, peroxide of lead appearing at the positive pole, and hanging from it in light threads or masses. The water frequently decomposes before the lead yields at all.

Nobilis Iris-Rings.—It is by the electrolysis of lead that the beautiful iris-rings are produced. A polished steel plate is put in a dilute solution of acetate of lead. The steel plate is connected with the positive pole of a galvanic battery, while a wire, connected with the negative pole, is put in the solution. Peroxide of lead is at once liberated on the steel beneath the wire, and a film extends outward, but growing thinner and thinner. Thus a series of concentric circles is formed exhibiting bright iris colors.

Nitric Acid.—Strong nitric acid conducts well and decomposes, oxygen appearing at the positive pole, nitrous acid and nitric oxide at the negative pole. Dissolution takes place, and the water becomes yellow.

Nitrate of Potash.—This is a good conductor, and yields secondary results.

Sulphurous Acid.—This, when diluted, yields oxygen at the positive pole, and hydrogen and sulphur at the negative.

Sulphuric Acid.—This yields sulphur at the negative pole, and produces secondary results.

Muriatic Acid.—A strong solution of this yields hydrogen at the negative pole and chlorine at the positive pole.

Electro-metallurgy.—The art of electro-deposition or the extraction of metals by the galvanic current. It is a result of the discovery of electrolysis—is, indeed, simply an electrolytic process.

Theory of Electrolysis.—The theory of electrolysis at present accepted is the following: In every compound one of the elements is electro-positive, the other electro-negative. Under the influence of the opposing electricities from the electrodes, decomposition and recomposition go on from one pole to the other. But these decompositions and recompositions are seen only at the electrodes.

This may be illustrated by the electrolysis of water. Water is composed of one atom of oxygen and two atoms of hydrogen. Oxygen is electro-negative and hydrogen is electro-positive.

When, now, the electrodes are dipped in water, the electro-negative oxygen of the molecule *a* (Fig. 29) is attracted to the positive pole, and the electro-positive hydrogen is repelled. The oxygen is then given off at the positive pole, while the liberated hydrogen unites itself with the next atom of oxygen of the molecule *b*, while the original atom of hydrogen is expelled.

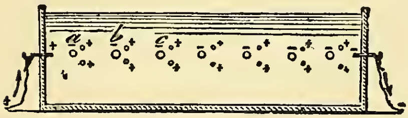

FIG. 29.

This atom of hydrogen unites with the oxygen of the molecule *c*, drives out the hydrogen with which that atom had been previously combined, and so on through the whole series of molecules until the negative pole is reached. Here the hydrogen has no more oxygen to combine with, so it is liberated as gas.

The electrolysis of all other electrolytes is similarly explained. This simple and ingenious theory was devised by Grotthüss in 1805.

Decomposed Elements Appear Only at the Electrodes.—In electrolysis the elements decomposed appear only at the electrodes; the intermediate region presents no change, although, of course, it must be traversed by the decompositions that occur. This is illustrated by the following experiment of Davy: Three vessels are connected by a cotton wick thoroughly moistened. In one vessel is placed an alkaline salt, and in the other two water. The liquid of all three vessels is colored with syrup of violets. When the galvanic current is made to pass through the vessels, the liquid at the negative pole becomes green, and the liquid at the positive becomes red, demonstrating that the acid goes to the positive and the alkaline base to the negative pole. The fluid in the middle vessel suffered no change of color, although it must have been traversed by the acid in the solution.

Electrolysis Compared with the Reactions in the Batteries.—It will be observed that the chemic action that takes place in the fluids of any battery is similar to electrolysis. The two are, indeed, facts of precisely the same nature. The action in the battery is accompanied by an electric current; the action in electrolysis occurs as a result of the passage of a current.

In the section on Electro-Surgery it will be shown that all these physical laws of electrolysis have a direct and necessary bearing on the use of electrolysis in surgery.

CHAPTER V.

INDUCED ELECTRICITY—CURRENT AND MAGNETO-INDUCTION—ELECTRO-MAGNETISM—ALTERNATE OR PERIODIC CURRENTS—THERMO-ELECTRIC CURRENTS.

Induced Electricity, or Electro-Magnetism: Electro-Dynamic Induction.—We have seen that induction means the action that electrified bodies exert on other bodies at a distance. Electro-static induction has already been treated of. We have now to speak of the induction of current-electricity.

Professor Oersted, of Copenhagen, first observed that the electric current, brought near a magnetic needle, caused it to deflect. This was the earliest observation in electro-magnetism.

Philosophers at once set themselves at work to explain this phenomenon. The discovery was not an accidental one on the part of Oersted. For years he had been occupied with the study of electro-physics, and as early as 1807 he had published a work in which he stated that he purposed to ascertain whether electricity in its most latent state had any effect on the magnet. His first discovery, that the needle had a tendency to place itself at right angles to the wire in which a current was passing, was a natural sequence and confirmation of his early researches. This discovery by Oersted formed another era in the science of electricity; for in 1820 the enthusiasm caused by the discoveries of Galvani and Volta had subsided, just as the enthusiasm caused by the Leyden jar and Franklin's kite had died away when Galvani made his renowned experiment.

Ampère's Theory of Magnetism.—Among the many scientists who sought to explain and unfold the phenomena of electro-magnetism as discovered by Oersted, it was reserved for Ampère to achieve the highest success. This theory, which was developed by rigid mathematical demonstrations, was that each molecule of a magnetic body is traversed by close electric currents. These currents are free to move about their centres of gravity, but the coercitive force, which is weak in soft iron but great in steel, tends to keep them in position.

Before a magnetic body is magnetized these molecular currents, or rings of electricity, by their mutual attraction neutralize each other, so that their combined action on any other substance is nothing.

When a body is magnetized, these molecular currents assume a parallel direction. The more complete the magnetization the more nearly parallel they become. When they are completely parallel, the limit of magnetization is reached. Ampère further supposed that all these molecular currents are equivalent to a single current circulating round the magnet. Still further, and in consonance with his theory, Ampère supposed that terrestrial magnetic effects were due to magnetic currents that circulate round the earth from east to west, perpendicular to the magnetic meridian. The resultant of these currents is a single current going from east to west. These currents, which are supposed to be due to the action of the sun, deflect magnetic needles, magnetize iron, etc.

The Electric Current Acts as a Magnet: Solenoids.—In confirmation of Ampère's theory of magnetism, it is found that when a helix, or spirals of covered wire, coated in such a way that one of the wires passes through the axis (solenoid, as it is called), is suspended into cups of mercury, and traversed by a current, it will act like a magnetic needle and point from north to south. Ampère gave the following rule by which the directions of the needle under the current can be understood: Let the observer imagine himself placed in the wire, so that a current enters at his feet and leaves at his head, while his face is turned toward the needle; the pole will always be deflected toward the left of the observer.

Helix.—In a helix of a copper wire through which a current circulates, each convolution of the spiral may be regarded as one of the little magnets of Ampère's theory. The ends of the spiral, when the current passes through it, act on a magnetic needle like the poles of a magnet. Ampère's theory explains two important magnetic phenomena.

1. Why like poles repel and unlike attract.

Two north poles of a magnet side by side have opposite currents and repel each other. Similarly with two south poles. But a north and south have currents in the same direction and attract each other.

2. Why a magnetic needle places itself north and south. A magnet can come to rest only when the current below it, nearest the earth, is parallel to the earth current. The magnetic needle turns to the north to allow the currents below it to become parallel to the earth's current.

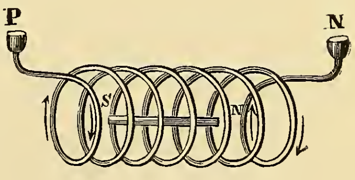

FIG. 30.

Electro-Magnetic Helix. — Magnetism is induced in a bar of soft iron by the simple passage of a current near it, in a direction at right angles to the bar. If, however, the wire (Fig. 30) encircles the iron many times, this effect will be much increased. Let a current be passed over the wire in the direction of the arrows, and the iron within will become strongly magnetic, with its poles as shown by the letters S and N. If the enclosed iron be not too heavy, it will be drawn to the centre and held suspended there.

When the current is broken, the iron ceases to be magnetic; while, if a bar of hardened steel be substituted for the iron, it will retain its magnetism permanently. Such a coil of wire is called a helix, from ἕλιξ, a winding, and a magnet formed in the manner described is termed an electro-magnet.

Fig. 31 represents the general form of an electro-magnet. It is composed of a bar of soft iron, bent into the form of a horseshoe. An insulated wire is coiled round its extremities. When a current of electricity is passed through the coil, the horseshoe bar becomes magnetic, and attracts the armature. If the current is broken, the bar becomes demagnetized and the armature falls to the ground. Permanent magnets possess much less power than electro-magnets.

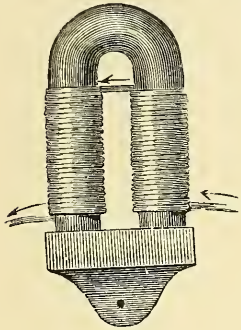

Fig. 31.

If the iron bar within the helix be more than a third of an inch in thickness, and the current be of moderate strength, the magnetism induced is in proportion to the strength of the current and of the number of turns in the coils. Additional coils of the wire give no increased magnetism, if the bar is thinner than one-third of an inch. In this case maximum is soon reached. Again, if the circuit is made very long, thus reducing the strength of the current, the advantage usually gained by the thick bar, and by increasing the number of coils, may be lost. The iron bar should be perfectly pure and well annealed, in order that the electro-magnet may quickly acquire and as quickly lose its magnetism on closing and breaking the circuit.

Direction of the Induced Current.—If a current of electricity is passed through any conductor, it will induce a current in the opposite direction in a second conductor situated parallel to the first. Let A B, Fig. 32, be a wire connected at either extremity with the poles of a galvanic battery, and M N a second wire parallel and near to the first. As soon as the circuit is formed and a current passes from + to −, a secondary current is induced in the second wire, but in an opposite direction.

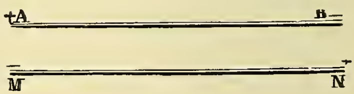

Fig. 32.

This current is, however, but for an instant. As soon as the circuit is broken, an instantaneous current, with its direction reversed, is again established in the second wire.

Different Orders of Induced Currents.—Induced or secondary currents have themselves the power of producing induced currents in other adjacent circuits. Currents thus induced from secondary induced currents are called tertiary induced currents. These tertiary induced currents have also the power of producing induced currents in an adjacent circuit, and so for a long series.

Currents produced in this way are in opposite directions alternately, and their strength diminishes the higher they ascend.

As a secondary current flows in a direction opposite to that of the battery current, so the tertiary flows in a direction opposite to the secondary. This law holds good throughout the whole series—the strength of the current diminishing as the distance from the battery increases.

If the primary coil be movable, so that it can be brought in closer proximity to the secondary coil while the current is passing, an inverse current is produced at the moment of its approach, the same as when the circuit is closed. If now the primary coil be withrawn, a direct current is

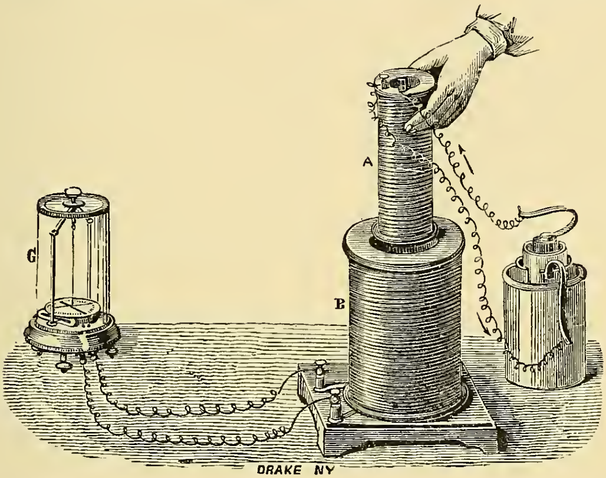

FIG. 33.

produced, the same as when the circuit is broken. As long as the primary coil remains in one position and the circuit not interrupted, all evidence of electricity in the secondary wire disappears. If, however, while in this position, the strength of the primary current be increased or diminished, momentary currents are established in the secondary coil; the inverse following the increase, and the direct current following the decrease in the strength of the primary current. In thus experimenting, it is much more convenient to wind the wires on separate bobbins, so that one may be placed within the other, as represented in Fig. 33.

Let A represent the primary coil, which is composed of No. 16 well-insulated wire, and B the secondary coil, of silk-covered wire, much longer than the other, and about No. 40. Now let the secondary coil be connected with the galvanometer, G, by means of the two binding screws, while the primary coil, by two loose and flexible wires, is placed in the circuit of a galvanic cell. As soon as A is inserted into B, a momentary inverse current is indicated. If it be withdrawn, the galvanometer indicates a momentary direct current. While the primary coil remains in the secondary, the needle announces the induction of currents according to the principles stated above, whenever the strength of the primary current is increased or diminished.

The Conditions under which Induction Takes Place.—To sum up in brief, induction takes place from one circuit into an adjacent circuit: (1) At the moment when the current is closed; (2) the moment when the current is opened; (3) while the current is increasing or diminishing in strength; (4) while the current is brought near to or removed from the adjacent circuit. A current that closes or increases in strength, or is brought near to an adjacent circuit, induces an inverse momentary current in that circuit. A current that opens or diminishes in strength, or is removed from an adjacent circuit, induces a direct momentary current in that circuit. It will be seen, therefore, that induction takes place only when there is some change in the condition of the inducing current. It must be closed or opened, increased or diminished in strength, brought near to or removed from the adjacent circuit.

In the ordinary electro-magnetic machines these changes are made by a current interrupter, and the strength of the current is modified by withdrawing or removing a metallic cylinder enclosing the coils, or by withdrawing or removing the core of iron wires.

Induction of a Current on Itself: Extra Current.—The extra current is that which is induced by the current in each coil on the other adjacent windings.

The windings act inductively on each other both at the opening and closing of the circuit. Thus we have a direct and an inverse extra current. The direct extra current gives shocks and sparks, decomposes water, magnetizes steel, and melts platinum wire. The electro-motive force of the extra current bears a uniform relation to the intensity of the primary or inducing current. When the secondary coil is closed, the extra current does not appear in the primary coil, but by what is called reaction it is formed in the secondary coil itself, and becomes an ordinary induced current.

It is called the extra current only so long as it remains in the primary coil; it so remains only when the secondary coil is open.

Current Interrupter.—Among the different contrivances for producing these changes in the primary current that are necessary for induction, the most convenient is the current interrupter.

In the ordinary apparatus for therapeutic purposes the vibrations range from about thirty to fifty per second, but to obtain certain physiologic and therapeutic effects much more rapid are often required—even as high as fifty thousand per minute. The higher grade of apparatus now allows of a large range of interruptions.

Fig. 34 represents a current interrupter. This when placed in the circuit of the primary coil, alternately closes and opens the circuit, producing induced currents in the secondary coils. E represents the terminal of the iron-wire core of the coil. The hammer D is attached to the spring, which is supported to a base in the primary circuit. At the centre of the spring is attached a disk of platinum, because that metal does not corrode; B is an adjustable platinum-tipped screw, supported by arm C, attached to post F. The thumb-screw A is for binding screw B firm when properly adjusted.

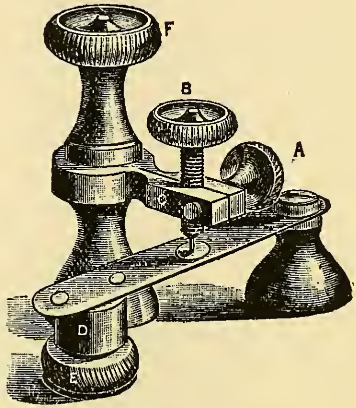

FIG. 34.

Object of the Iron Core in the Primary Coil.—The inductive power of the primary current is very greatly increased by putting a bar of soft iron or a bundle of iron wires in the heart of the primary coil. The iron core becomes magnetic by the action of the current, and when the current opens the rapid demagnetization induces a current in the same direction as the disappearing primary current. Pushing it in the coil increases the current, withdrawing it diminishes the current. This, however, is but little used, as more perfect devices are now to be found.

A bundle of wires is preferable to a single bar of soft iron, for in the latter currents are formed which impede the sudden cessation of the primary current, while in the former these cannot be formed.

Thickness and Length of the Outer and Inner Wires.—It is a law of electro-physics that wires of a large diameter conduct electricity better than wires of a small diameter. It is necessary that the primary current should be strong, since its principal object is to excite magnetism in the core; consequently the coil is made of medium wire and of moderate length. The secondary coil, however, is made of very fine wire and of great length, so that as many turns as possible may be brought within the influence of the primary coil, and thus produce a secondary current. As with the galvanic or inducing current, the electro-motive force of the battery is proportionate to the number of cells; so with the induced or secondary current, the electro-motive force of the coil is proportionate to the number of turns.

Induction Coils and Electro-Magnetic Machines.—The usual induction coils for philosophic or electro-therapeutic purposes consist of two helices or coils of wire enclosing a bar of soft iron or a bundle of iron wires.*

* In the machine of Kidder, to be described under Electro-Therapeutics, the helix is composed of three or more coils of wire, not distinct, but connected.

The inner coil is connected with the poles of a battery, and there is a device for breaking the current. The inner coil is composed of tolerably coarse wire, and is comparatively short. The current that is developed is called the primary, or sometimes the inducing, current. The outer coil is in no way connected with the inner coil, but by induction from the current of the inner coil as it is alternately broken and closed a powerful current is established in this coil. The outer coil is composed of fine wire, and it is very much longer than the inner coil.

The finer and longer the wire, the greater the tension of the current. The current that comes through the outer coil is called the secondary current, in distinction from that which comes from the inner coil, which is

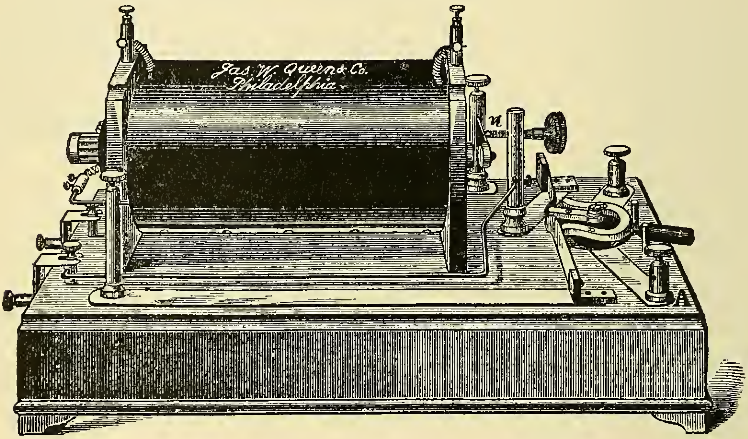

FIG. 35.

called the primary. In both coils the copper is insulated with silk covering.

Ruhmkorff's Coil.—The most powerful of all coils, and the one best adapted for philosophic experiments, is that of Ruhmkorff (Fig. 35). It is about fourteen inches in length. The inner coil is of copper, is about 2 mm. in diameter, and four or five yards long. It is coiled on a cylinder of cardboard, and is enclosed in an insulating cylinder of glass or rubber.

The wire of the outer coil is of copper, from $\frac{1}{5}$ to $\frac{1}{3}$ mm. in diameter, and from thirty to sixty miles in length. The distinctive features of this coil are these:

1st. It is coiled in sections so as to avoid the induction of the outer coil on itself, which is liable to take place when it is very long and the tension is high, however thorough the insulation.

2d. The insulation is very complete. The wire is covered with silk, and each winding is separated from the others by a layer of shellac. In the larger coils of Ruhmkorff the induced currents are thousands of times stronger than the primary current that excites them.

The Condenser of Ruhmkorff's Coil.—The intensity of the current of the secondary coil is increased by interposing a condenser in the circuit. In Ruhmkorff's coil the condenser consists of 150 sheets of tinfoil 18 inches square, and with a surface of about 75 square yards. These sheets are coiled around insulating oiled silk, and around each other, so as to form two armatures, and the whole is placed below the helix in the base of the apparatus.

Being introduced into the circuit, it receives the extra current and increases its tension. It stores up and utilizes force that would otherwise be wasted in the form of sparks at the interrupter.

Effects Produced by Ruhmkorff's Coil.—The tension of Ruhmkorff's coil is enormous, and for the reasons above given—the length and fineness of the secondary wire and the power of the condenser. It possesses all the properties of static as well as dynamic electricity. It is capable of giving a violent shock. It causes fine iron wire to melt and burn with a bright light. It can rapidly decompose water, or produce luminous effects in the water without decomposition.

It decomposes and combines gases. Passed through a hermetically sealed tube containing air, it forms nitrous acid from the nitrogen and oxygen. It can produce a spark eighteen inches in length in the air.

In *vacuo* it produces most remarkable effects. In the so-called electric egg, a luminous trail is observed between the poles. At the positive pole the light is red and brilliant; at the negative, feeble and violet. If vapor of alcohol, or turpentine, or bisulphide of carbon, be introduced into the vessel, it appears in the form of alternate light and dark zones or strata. The tints vary with the nature of the vapor. The same phenomena are obtained by the ordinary galvanic current from a large number of cells. The luminous effects of the coil can be varied by varying the selection of cells operating.

In electro-therapeutics a wide variety of electro-magnetic machines have been devised. Most of them are run by one or two cells, like Smee's or some modification of Bunsen's bichromate, together with some forms of hermetically sealed cells, otherwise known as "dry cells," and the current generated is just sufficient for application to the human body, and are but little adapted for the philosophical room.

One of the largest induction coils of which we have any knowledge is that of Mr. Spottiswoode's, which yields a spark of 42½ inches in length in air when operated with 30 Grove batteries. To appreciate somewhat this enormous coil, it might be well to state that the secondary coil contains 280 miles of wire, with 340,000 turns, and has a resistance of over 100,000 ohms.

Properties of Induced Currents.—Induced currents have in different degrees all the properties of the ordinary galvanic current. They produce chemic, thermic, luminous, and physiologic effects. They deflect the magnetic needle, magnetize steel, and are capable of themselves exciting induced currents. There is a difference, however, between the effects of the direct induced and inverse induced. The direct gives a powerful shock, the inverse a mild shock.

The direct magnetizes to the point of saturation, the inverse does not magnetize.

In their action on the galvanometer they are about equal. In quantity, the direct and inverse induced currents are about the same; but the tension of the direct induced is greater than that of the inverse induced.

Comparative Chemic Effects of the Galvanic and Induced Currents.—That the chemic character of currents of induction is distinctive from the galvanic is proved by the following experiment: When the platinum poles connected with an induced current are placed in water, water is decomposed and oxygen produces oxidation of platinum, which is reduced to metallic platinum by the recombination of the hydrogen with the oxygen.

If a solution of iodide of potassium and starch is brought into the circuit, the blue color appears first at the positive pole. When the galvanic current is used, the blue color appears only at the positive pole. When the induced current is sent through water it decomposes it, just as the galvanic current does, the oxygen and hydrogen predominating at the positive pole.

Magneto-Electricity.—Magneto-electric induction is the induction of electric currents by magnetism. It is, as the term implies, the reverse of electro-magnetic induction. There are two forms of magneto-electric induction.

The first and most familiar form is when a current is induced in a coil of insulated wire. The second form is when a current is induced in conducting plates.

Under electro-magnetic induction we have seen that the coil of wire in which a current circulates produces a contrary induced current in an adjacent coil whenever a change is made in the current by opening, closing, withdrawing, or approaching it. The strength of the induced current is proportioned to the amount and suddenness of these changes. If now we substitute for the primary or inducing coil a permanent bar magnet, and cause it to approach or withdraw from the adjacent coil, it induces a current in that coil. This principle is the basis of all the magneto-electric machines that are so familiar to students of philosophy, and that were once so much used in electro-therapeutics.

The development of magneto-electricity is shown in a very simple manner by the common horseshoe magnet, its armature, and a copper disk.

Faraday's disk machine (Fig. 36) consists of a copper disk rotated between the poles of a permanent magnet. The current traverses from shaft to rim, or *vice versa*, according to rotation.

In the electro-magnetic machines in ordinary use a soft iron armature covered with wire is made to rotate at the poles of a permanent horseshoe magnet. As the armature rotates, its two ends are, of course, alternately brought near to and removed from the poles of the magnet, and thus two currents are induced in the wires that cover the armature. Each current lasts half of a revolution, and if the rotation be rapidly kept up a current is produced which may be perceived when the ends of the wires are joined.

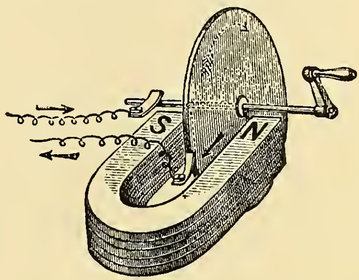

FIG. 36.

A Continuous Current from Magneto-Electric Machines.—When the armatures of the magneto-electric machine are made to revolve with sufficient rapidity, a continuous current is produced which has all the properties of the galvanic current. Magneto-electric currents are, therefore, extensively used in electrolytic experiments and in electroplating. Some of these are utilized in electro-therapeutics, but are not to be recommended.

Currents Induced by Magnetism in Conducting Plates: Magnetism of Rotation.—In 1824–25 Arago discovered that when a copper disk revolved with great rapidity under a needle resting on a disk above the disk, the needle deflected in the direction of the motion of the disk. After a time, if the movement be sufficiently rapid, the needle refuses to remain fixed, and turns around after the disk. The explanation of this phenomenon was given by Faraday in 1831. He showed that it arose from the reaction of the currents induced in the plate by the magnet. The magnetism of rotation is only one of the many phenomena connected with induction. All these phenomena—induction by currents of magnetism and by rotation—are explained by the theory of Ampère, before cited. They are at once in harmony with that theory and confirmatory of it.

History of Induction.—The discovery that electric currents of magnetism can induce currents in neighboring circuits was made by Faraday in 1830. His researches on the subject were published in the Philosophical Transactions in 1831 and 1832.

This discovery of Faraday, like that of Oersted, was the result, not of accident, but of long and laborious experimentation. As early as 1825 Faraday had sought to make a wire, through which the galvanic current was passing, induce a current in a neighboring wire, just as a conductor charged with franklinic electricity would have done. Not until 1831 did he find out that the current must be broken or closed, or approached or withdrawn, before it could induce a current in a neighboring wire.

In 1832 Professor Henry, then of New Jersey, now of the Smithsonian Institution, Washington, observed phenomena which in 1834 Faraday showed were due to the extra current. In 1837 Bachhoffner and Sturgeon showed that a bundle of wire was better in an induction apparatus than a rod of soft iron.

In 1841 Professor Henry studied the inductive action of currents on currents. In 1850 or 1851 Ruhmkorff constructed the induction coil, and in 1853 Fizeau greatly increased its power by adding to it a condenser. The discovery that discharges of the Leyden jar made a primary spiral induce a current in a secondary spiral, and that currents of the third, fourth, and fifth order can be thus produced, and of sufficient strength to give shocks, burn, etc., was made simultaneously by Professors Henry, of Washington, and Riess, of Berlin.

The first magneto-electric machine was made by Faraday in 1831. The first machine of the style now used was made by Pixii in 1832. Improvements have been since made by Saxton (1833), Clarke (1836), Petrine (1844), Stöhrer (1844), Siemens, Halske, Duchenne, and others.

Alternate or Periodic Currents.—A simple coil revolving in a magnetic field induces electro-motive forces which at every half-turn change in direction and give rise to alternate currents. There is an electro-motive force in each whole revolution, which after rising to a maximum dies away and is immediately followed by a reversed electro-motive force, which in its turn reaches a maximum and dies away. This process is called a period, and the number of periods taking place in a second is called the frequency or periodicity of the alternations. The currents resulting from these periodic or alternating electro-motive forces are also periodic and alternating. The ordinary current of induction attains its maximum very rapidly, while the so-called alternating or periodic current attains its maximum more gradually, and can be represented graphically by a curved line, that is more or less undulated because of the phenomena of self-induction. The current sinusoidal differs from the alternating current in that the undulations are perfectly regular.

THERMO-ELECTRICITY.

Thermo-electricity is that form of electricity that arises from the heating of two heterogeneous conductors at their junction. The two most important methods of generating thermal currents are, 1st, with two portions of the same metal; and 2d, with two different kinds of metal.

Thermo-Electricity Generated by One Metal.—If a copper wire be cut into two pieces, and one of the ends be heated to redness and pressed against the end of the other piece, a current of electricity is produced. This is demonstrated by the galvanometer.

When different portions of the same metal have different structures, a current is obtained when the point where both structures come together is heated.

If, for example, a platinum wire be twisted or bent on itself, this twisting so changes the structure of the wire that a current is generated by heating the point of union between the twisted and non-twisted portion.

Thermo-Electricity Generated by Two Metals.—Let A and B (Fig. 37) be respectively bars of antimony and bismuth, soldered together.

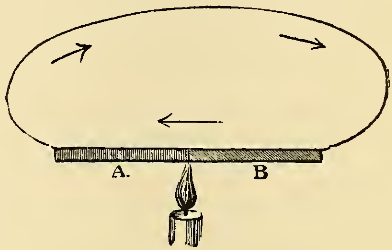

FIG. 37.

When the junction of the metals is heated, a current of electricity is generated, which flows from the bismuth to the antimony, as shown by the arrow. If the junction is chilled by applying ice, a current is also produced, but in the opposite direction. This combination constitutes a thermo-electric pair.

Thermo-Electric Batteries.—A number of thermo-electric couples soldered together so that the copper or antimony of one is soldered to the bismuth of the other, and so on, is called a thermo-electric battery. The current is generated by heating one row of the soldered faces, or, as the current depends on the difference of temperature of the two sides, by applying ice to one side and heat to the other.

Thermo-electric batteries of any form are not used to any extent in electro-therapeutics. The hopes at one time entertained of them have been disappointed. In practice they have been found to be inconvenient, bulky, expensive, and untrustworthy.

CHAPTER VI.

OHM'S LAW AND ITS PRACTICAL APPLICATION TO ELECTRO-THERAPEUTICS.

THE basis of all electric measurement is Ohm's law, which was thus originally stated: The strength of the current varies directly as the electro-motive force and inversely as the resistance of the circuit.

Putting C for current, E for electro-motive force, and R for resistance, the law is thus expressed: $C = \frac{E}{R}$.

This law was discovered by Professor Ohm, of Nuremberg, in 1827, and for a long time was neglected. It is the north star of electro-therapeutics. Those who can keep this always in sight need never lose their way, however long or intricate the explorations they may make in this important and fascinating realm. Although originally nothing but a theory, yet it has been powerfully confirmed by the mathematical calculations of many physicists, and has proved itself competent to explain all the phenomena with which it has to do. Just as the strength of the theory of gravitation consists in its power to account for the movements of the solar system, just as the strength of the undulatory theory consists in its power to explain the complex phenomena of light, so the strength of Ohm's law consists in its power to account for the phenomena of electricity. As no one can be master in astronomy without understanding gravitation, or in optics without understanding the undulatory theory, so no one can be master in electricity without understanding Ohm's law.

We shall endeavor to make this law and its application as clear as the nature of the subject will allow. It is necessary to define certain terms that are not very familiar; first of all, units of measurement.

A unit is any given quantity with which others of the same kind are compared for purposes of measurement, and in terms of which their magnitude is stated.

Siemen and Varley each established a unit of resistance which was recognized up to 1864, when upon the suggestion of Weber the British Association established an absolute unit of electric resistance. This was accepted until the meeting of the Electrical Congress in Paris in 1881, when some modifications were made. The units here expressed are such as have been defined by the International Congress of Electricians, Chicago, 1893. Many electric units have been established, but those of practical benefit to the physician using electricity therapeutically—ohm (resistance), volt (pressure), ampere (current)—are here explained.

An ohm is a unit of resistance and is represented by the resistance offered to an unvarying electric current at the temperature of melting ice by a column of mercury 14.4521 gm. in mass, of a constant cross-sectional area, and 106.3 cm. long.

One million ohms equals one megohm; one millionth of an ohm equals one microhm.

The volt is the unit of electro-motive force, that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere.

The ampere is the unit of current, represented by the unvarying current which, when passed through a solution of nitrate of silver in water, in accordance with certain specifications, deposits silver at the rate of 0.001118 of a gramme per second.

Ohm's law says nothing about the energy or power conveyed by a current, and in electro-therapeutics we have little use for the coulomb, the unit of quantity; the farad, the unit of capacity; the joule, the unit of work; or the watt, the unit of power.

The terminology of electricity in general has been atrociously difficult and obscure, but nowhere has there been deeper obscurity and grosser misunderstanding and inconsistency than in the application of the terms resistance, quantity, tension, and electro-motive force.

Electro-Motive Force.—The electro-motive force is the force that urges forward the current.

It is the origin of tension, to be hereafter defined. This force is modified—

1st. By the nature of the plates of which the element is composed.

2d. By the nature and strength of the acid solution.

3d. By the number of elements in the solution.

Substances that stand at or near the two extremes of the electro-positive and electro-negative series generate a stronger electro-motive force than substances that stand near each other.

Zinc and platinum or zinc and carbon give more electro-motive force than zinc and copper, because the difference in their oxidability is greater, and they stand farther apart in the electro-positive and electro-negative series.

Plates that are imperfect in their structure, or which contain impurities that generate currents in opposition to the main current, or plates that are worn out, or are encrusted with the products of chemic decomposition, give less electro-motive force than plates that are perfect, fresh, and clean.

Similarly also the electro-motive force is diminished by the polarizing action in the cell. Thus, in the Smee cell, the hydrogen that gathers on the platinum plate and the oxygen that gathers on the zinc, generate a current that is opposite in direction to the main current, and enfeebles it ; and for this reason, lifting the plates out of the liquid a moment to allow the gases that form on them to escape, or agitating the liquid, at once increases the electro-motive force. Strong acids which excite vigorous chemic action give more electro-motive force than weak acids, and therefore it is that sulphuric and nitric and chromic acids are so much used in batteries.

When the proportion of acid in the solution is large, electro-motive force is greater than when it is small. Strong solutions, however, consume the plates faster, and the electro-motive force will be reduced thereby sooner, other conditions being the same, than when weak solutions are used.

The electro-motive force is exactly proportioned to the number of elements, without regard to their size. Two elements give twice as much electro-motive force as one element, and one hundred elements give one hundred times as much as one element of a similar character. This can be proved by a galvanometer, with a long resistance-coil, where the deflection of the needle will be in pretty exact proportion to the number of cells brought into the circuit. The exactness of this proportion is of course modified by the imperfections of individual elements, or by variation in the quantity and strength of solution in each cell; but the law always holds good.

As with the long-coil galvanometer, so with the human body, or any other powerful resistance whatsoever, the electro-motive force that passes through it will be—all other conditions being the same—proportioned to the number of elements and without regard to their size. If a series of very large elements are opposed to an equal series of very small elements of similar construction, no current will pass ; they will neutralize each other. If both be tested by the galvanometer with a long resistance, they will cause similar deflections of the needle.

The current that passes through a circuit is directly proportioned to the electro-motive force. If there were no resistance in the circuit, current and electro-motive force would be the same: $C = E$. But there can be no circuit without some resistance, therefore C never equals E.

Tension, or Potential.—Tension is that quality of electricity by which it overcomes resistance. This definition is practical rather than strictly scientific, and can only be understood by explanation.

Tension is a result of the electro-motive force, and is dependent on it, and by mistake the two are often confounded. The sum and the differences of electro-motive force are always equal to the sum and differences of tension, but they are differently distributed in the circuit. By mathematicians the term potential, suggested by Green, is preferred to tension. The term is a relative one, and no body or part of a body can be said to have an absolute tension or potential. The potential of a body is really the difference between its potential and that of the earth, which is assumed to be zero. Electricity flows from a body or part of a body at a higher potential, to a body or part of a body at a lower potential, and the work which it does measures its amount. Differences of potential may be compared to differences of level for water. As water tends to flow from a higher level to a lower level until all is of a uniform height, so electricity tends to flow from a higher to a lower potential until the potential of all parts of the conductor is the same, and ceases to flow. An instance of extreme tension is found in lightning, where it is caused by the differences in the electro-motive forces between two clouds, or between the clouds and the earth.

The tension of the frictional machine is very great, for the reason that it is not at all influenced by the resistance of the circuit, which in the galvanic battery is very great. If the current of the galvanic battery encountered no resistance in the circuit, or was not affected by resistance, its tension would be enormous.

The term intensity has long been used as synonymous with tension; but, strictly speaking, intensity is derived from the French *intensité*, which has been translated intensity, but which really means quantity. It is better to dispense entirely with the term intensity, and we have done so in the present work.

Our definition of tension may be thus illustrated: Let a battery of one hundred cells be joined in the ordinary tension arrangement in series, zinc united with carbon, and so on. Place the battery on an insulated stand, and connect the zinc or negative pole with the earth, leaving the other free. Regarding the earth, for convenience' sake, as zero, the zinc pole will have a tension of 0, while the free end will have a tension of 100 positive. If a wire be connected with the free end, a current would flow from it to the earth. If now we reverse the position of the poles, connecting the carbon pole with the earth, and leaving the other free, the carbon end will be 0, and the zinc end will be 100 negative, and if it be connected with the earth a current will flow from the earth to it. In both of these cases the tension is the same; in one case it is positive, in the other negative. Take the same battery, with the zinc pole connected with the earth, and join the carbon and zinc ends by a short, thick wire, and a strong current will flow through the wire. But here comes in the difference between tension and electro-motive force, for it can be ascertained by proper tests that the electro-motive force of the battery is the same as it was before the ends were joined, but the tension has changed. Before it was 100 positive at the carbon end, now it is almost 0.

If, instead of a short, thick wire, a long, fine wire that offers greater resistance be used to connect the poles, the tension at the carbon end will rise with the increase in resistance in the wire. When the resistance becomes infinitely great, the tension becomes 100 again, but it can never exceed 100, for the tension can never exceed the electro-motive force at any point, although it may fall very much below it.

The arrangement in series (or, as it is erroneously called, "intensity arrangement"), is when the electro-positive element of one cell is united to the electro-negative element of the next cell, and so on. The "quantity arrangement," or "parallel," is when all the electro-positive elements are united to all the electro-negative elements so as to make one large element. The arrangement in series, or a "tension arrangement," is used for all ordinary galvanization and electrolyzation. The parallel or "quantity arrangement" is used in galvano-cautery. The phrases "joined for tension," or "intensity," and "joined for quantity," are relics of old and exploded theories of electricity. For convenience' sake they are still used ; but those who understand Ohm's law need not be deceived by them.

Resistance.—Resistance is that quality of a conductor that impedes the passage of a circuit.

There are two kinds of resistance in any circuit:

1st. That of the battery itself (internal resistance).

2d. That of the connecting wires (circuit outside of the battery), the human body, or other substance introduced into the circuit (external resistance).

How Resistance is Modified.—Resistance is modified in three ways:

1st. By the nature of the substance, whether liquid or solid, or by its special chemic composition.

2d. By the form of the substance, whether long or short, of small or large diameter.

3d. By the temperature.

It is proved by experiment that the resistance of wires of the same material and of the same thickness are directly proportioned to their length, and inversely proportioned to the squares of their diameters.

A wire one mile in length gives twice the resistance of a wire half a mile long, and four times the resistance of a wire one-fourth of a mile long. On the other hand, wires of the same metal, but of diameters which stand to each other in the relation of 1, 2, 3, offer a resistance which stand to each other as 1, $\frac{1}{4}$, $\frac{1}{9}$. In other words, the longer the wire the greater the resistance, the thicker the wire the less the resistance. The same law, but less exactly, applies to liquids, and for this reason large elements give less resistance than small elements. The relative specific resistances of a number of metals at a temperature of 32° F. are as follows:

Silver	1	Iron	6.46
Copper	1.06	Lead	13.50
Gold	1.38	Platinum	11.3
Zinc	3.75	Mercury	62.50

The converse of resistance is conduction.

The following table of the relative conductibility of metals at 32° F. is taken from Latimer Clark. It will be perceived that it varies somewhat from the above table of relative resistances:

Silver	100	Iron (pure)	16.81
Copper (pure)	99.9	German silver	7.6
Brass	20	Tin	12.4
Gold	76	Lead	8.3
Zinc	29.5	Platinum	17
Steel	16	Mercury	1.6

It will be seen that both estimates agree in making copper and silver the best conductors, and for that reason copper wire is so much used in making battery connections. In both tables platinum stands low in conductibility, and for that reason platinum wire is used when, as in galvano-cautery, it is required to generate heat by passing the current through a resisting medium. If mercury could be made in the form of a wire it would of course be better than platinum, since its resistance is somewhat greater. Bismuth, graphite, and coke rank still lower in conducting power than mercury. The resistance of liquids is enormous. Thus, taking copper wire at 32° F. as 1, the resistance of a saturated solution of sulphate of copper at 48° F. is 16.885.520 ; ditto of chloride of sodium at 56° F., 2.903.538 ; ditto of sulphate of zinc, 15.861.267 ; sulphuric acid diluted to $\frac{1}{10}$ at 68° F., 1.032.020 ; nitric acid at 55° F., 976.000 ; distilled water at 59° F., 6.734.208.000.

It has been estimated that the human body, by virtue of the salts which it contains, conducts fifteen or twenty times better than water, provided the skin be fully moistened; and that copper conducts from three to four hundred million times better than the human body.

Effects of Temperature on Resistance.—Resistance is more or less modified by temperature.

Temperature affects temporarily the conducting power of metals. Nearly all pure metals increase their resistance about 0.4 per cent. for a raise of 1° C. in temperature, or about forty per cent. when warmed 100° C.; but this varies with different metals. Conductivity is increased by annealing. Non-metallic substances increase in conductivity as they rise in temperature. Water, for example, when heated conducts better than water cold. When a current passes from a liquid to a solid, or *vice versâ*, the resistance is very great.

All Resistance Relative.—No substances absolutely resist the passage of electricity; even resin, glass, and sulphur, the worst conductors, do conduct a slight current, as can be proved by a very delicate galvanometer.

No Perfect Conductor.—Even the best conductors, as copper and silver and gold, are imperfectly so ; they all resist the current more or less.

This can be shown with the galvanometer, which, when brought directly into the circuit, shows a deflection of the needle. When short wires of copper or silver are interposed the deflection is lessened.

If we now comprehend the terms electro-motive force and resistance, we shall have no difficulty in comprehending the term current strength, for, according to Ohm's law, the current varies directly as the electro-motive force and inversely as the resistance.

Ohm's law expresses the relation in an active electric circuit of current, electro-motive force, and resistance. These three factors are always present. In an active electric circuit the current is equal to the electro-motive force divided by the resistance.

This law can be expressed in various ways, and may be given as a collection of rules:

1. Current is equal to the electro-motive force divided by the resistance: $C = \frac{E}{R}$.

2. Electro-motive force is equal to the current multiplied by the resistance: $E = C \times R$.

3. Resistance is equal to the electro-motive force divided by the current: $R = \frac{E}{C}$.

From the above, knowing the value of any two, we can readily ascertain the value of the unknown—that is, knowing the value of the electro-motive force and the resistance, we can ascertain the current strength. Current is equal to electro-motive force divided by the resistance.

If the current strength and resistance are known, we can calculate the electro-motive force. Electro-motive force is equal to current multiplied by the resistance.

Electro-motive force and current known, we can determine the resistance. Resistance is equal to the electro-motive force divided by the current.

The current is the amount which passes through the circuit at any given time.

This depends, according to Ohm's law, on two factors—the electro-motive force and the resistance. The current varies directly as the electro-motive force; and if there were no resistance, current would be precisely the same as electro-motive force. But the current strength varies inversely as the resistance, and therefore, to find out what the strength of any current is, we divide the electro-motive force by the resistance. The fraction thus formed is the strength of the current, as we commonly call it. There are, as we have seen, two kinds of resistance—that in the battery and that in the circuit outside of the battery. Both of these must be taken into account in estimating the relation of the different kinds of batteries, and in selecting batteries for special kinds of work. Let E be the electro-motive force, R the resistance of the circuit outside of the battery, r the resistance in the battery; then $\frac{E}{R+r} = C$, the strength of the current—the number of units of electricity that flow through the circuit in a given time. The correctness of this mathematical conclusion may be demonstrated on a galvanometer that has only a short resisting wire ; one cell will deflect the needle nearly as much as one hundred cells. Again, when any number of cells are joined together with great external resistance, such as is offered by a long, fine wire, or by the whole human body, for example, the current that flows through the circuit will increase with the increase in the number of cells.

There is no inconsistency between these phenomena. It is indeed a part of and a conclusion from Ohm's law. Everything depends on the external resistance. Although in this case, as in the other, each added cell brings in its own internal resistance that counterbalances the electro-motive force, yet the internal resistance bears so small a proportion to the large external resistance that the current flowing through the circuit will be pretty directly proportioned to the number of cells.

Still keeping Ohm's law before us, we can demonstrate this mathematically.

Let the electro-motive force of any cell be 1.5 volts, and the internal resistance be 2 ohms, and the external resistance afforded by the human body 5,000 ohms. The strength or amperage of the current could be thus represented:

$$\frac{1.5 \text{ electro-motive force}}{2 \text{ internal resistance, and } 5{,}000 \text{ external resistance}} = \frac{1.5}{5002} = \frac{1}{3334}, \text{ or about } \tfrac{1}{3} \text{ of a milliampere.}$$

Again, we may illustrate this as follows:

One hundred cells are joined together and the ends are connected by a conductor of high resistance. Let the electro-motive force of one cell be 1.5 volts or units of electro-motive force, then the electro-motive force of 100 cells will be $100 \times 1.5 = 150$ volts. Let the resistance in each cell be .5 ohms or units of resistance, then the resistance in the 100 cells will be $100 \times .5 = 50$ ohm. Let the resistance of the external conductor be 5,000 ohms: now, in order to find the number of amperes of electricity—that is, the strength of the current that flows through the connecting wire—divide the electro-motive force by the resistance, and we have this fraction:

$$\frac{150 \text{ electro-motive force}}{5000 \text{ resistance of wire, and } 50 \text{ resistance of battery}} = \frac{150}{5050} = \frac{3}{101}, \text{ or about } 30 \text{ milliamperes.}$$

This fraction represents the current strength in milliamperes that flows through the wire.

We may illustrate this law by supposing a current of water passed through an ordinary syringe. The quantity of water that flows through the tube will be directly proportioned to the force with which it is urged forward by the piston; this force would correspond to electro-motive force. The friction will correspond to the internal and external resistance of the battery. Now if we divide the one by the other, we have the quantity of water which in a given time flows through the tube, or the strength of the current. In this way we can find the number of cubic inches of water that flow through the tube in a second of time, just as we canfind the number of amperes, or units of current strength, that flow through a circuit. It follows from all this, of course, that if the electro-motive force be very greatly increased, the resistance being the same, the current must be increased; but if the resistance be increased in proportion to the increase of the electro-motive force, the current will not be any greater.

Absolute and Actual Strength of Current.—It also follows that the absolute current of any battery—the amount that it is capable of generating—may be very much greater than the actual current that it sends through a circuit. Everything depends upon the resistance, whether it be small or great.

The Relation of Current Strength and Quantity.—This strength of current about which we say so much is measured in amperes. On the other hand, the quantity of electricity conveyed by a current of one ampere in one second is called an ampere second, or one coulomb. If C represents the amepres of current, t the seconds that it lasts, and Q the number of coulombs transmitted, their relation is expressed by the formula: $Q = C \times t$.

In electro-therapeutics we have not yet found the same necessity of estimating the actual quantity of electricity as we have the current strength, and therefore the coulomb, the unit of quantity, is not of the same practical value in medicine as the ampere, the unit of current strength. And yet it is quantity that decomposes chemic substances, as water, salts, the human body, etc. Hence electrolytic operations largely depend on the quantity of electricity that flows through the tissues acted on. It is quantity that accomplishes much of the therapeutic effect of the different forms of electrization—although tension alone, with very small quantity, may, as in the case of frictional or franklinic electricity, be capable of therapeutic effects. Franklinic electricity, however, relieves and cures disease by changing the electric condition of the patient, by giving a positive or a negative charge, more than by the passage of the current through the body, and the consequent electro-tonic and chemic changes. Ordinary faradic or voltaic electricity, on the other hand, does not, as many suppose, charge the patient with electricity, and does not, by its direct action, leave any more electricity in the body than it finds there. If they increase or diminish the natural electricity of the body, it is indirectly through the effect of quantity of electricity passing through the tissues and improving nutrition.

Under this head come these important practical conclusions:

First. If any large number of cells every way similar are joined in a short circuit by large connecting wires, and without any other external resistance, there will be no more current flowing than if a small number of similar cells were so joined.

Although each additional cell increases the electro-motive force, yet it also increases the resistance, as we have already seen, and this increase of resistance will counterbalance the increase of electro-motive force, so that the amount of electricity that flows through the circuit will be about the same. Ohm's law will demonstrate this mathematically. Let the electro-motive force of any cell be 1.5 volts or units of electro-motive force, and the resistance of each cell be 2 ohms, or units of resistance, and the resistance of the short wire 2 ohms. Dividing the electro-motive force by the resistance, we have for 10 cells:

$$\frac{1.5}{2} \times \frac{10}{10} = \frac{15}{20+2} = \frac{15}{22}$$

or about 675 milliamperes = the current that 10 cells send through the circuit.

Now let there be 50 similar cells, and our fraction will be:

$$\frac{1.5}{2} \times \frac{50}{50} = \frac{75}{100+2} = \frac{75}{102}$$

or about 675 milliamperes—a fraction that varies very slightly from $\frac{15}{22}$. Let there be 1,000 cells, and we have this fraction:

$$\frac{1.5}{2} \times \frac{1,000}{1000} = \frac{1,500}{2000+2} = \frac{1,500}{2002}$$

Secondly. Large cells connected by great external resistance, as the human body, or a galvanometer with a long resistance coil, do not send more quantity of electricity through that external resistance than similar small cells.

The electro-motive force of large cells is no greater than that of similar small cells, as we have already seen. The resistance is less because the surface of the plates is greater, and the greater the section the less the resistance, as has already been shown. But the little advantage thus gained from large cells by a diminution of resistance bears so small a proportion to the great external resistance of the human body, or of a very long wire, that the current actually sent through the circuit will not be materially increased—at least, by any reasonable number of cells.

Here again Ohm's law comes to our assistance, and fortifies our statement by a rigid mathematical demonstration. Let us suppose a battery of 100 small cells. Let the electro-motive force of each cell be 1.5 volts. Let the internal resistance of each cell be 2 ohms. Let the external resistance of the human body, through which the current is to be made to pass, be 5,000 ohms. Now, by Ohm's law, to find the current of electricity that flows through the human body when enclosed in the circuit, we divide the electro-motive force by the internal and external resistance, as follows:

$$\frac{1.5}{2} \times \frac{100}{100} = \frac{150}{200 + 5000} = \frac{150}{5200} \text{ or } \frac{3}{104}$$

Let us now suppose 100 similar very large cells. The electro-motive force would be the same, the external resistance would be the same. But the internal resistance of the battery would be less because the surface is greater.

By a law previously explained, the resistance varies inversely as the square of the section. For convenience' sake, we will suppose the resistance of the large cell to be $\frac{1}{4}$ that of the small ones—that is, .5—and Ohm's law will give us the following fraction:

$$\frac{1.5}{.5} \times \frac{100}{100} = \frac{150}{50 + 5000} = \frac{150}{5050} = \frac{3}{101}$$

—a fraction that is, it is true, a little larger than $\frac{3}{104}$, but not enough to be worth considering.

The same truth may be shown by a galvanometer that has a long resistance coil. If the fluid be raised just a little, so that the elements are just immersed and the poles are connected with such a galvanometer, a certain deflection of the needles will take place, according to the number of cells. If now we raise the fluid still higher, so that all the elements are immersed, and four or five times as much surface is brought into action in each cell, the needles will not be much more deflected, but will remain at nearly the same point where it was when the elements were first immersed. This is an experiment that we have made repeatedly.

For the galvanometer substitute the human body from the hand to the legs, and we can understand the great fact that large cells do not send a stronger current through the body than small cells of similar character.

In electro-therapeutics, as in telegraphy, electro-metallurgy, and other uses, large cells have this advantage, that they last longer and do not require so frequent cleaning and filling.

Although they cannot in a given time send through the human body, or long lines of wires, any greater current than small cells, yet their reserve force is much greater, and in proportion to their size they will hold out longer and keep up a more uniform current.

Large cells may, for electro-therapeutic purposes, have the advantage of steadiness of current ; there would appear to be less fluctuation in the strength of the current from moment to moment than when the cells are small.

In small cells the degree of the internal resistance and the extent of the chemic action may vary more or less from moment to moment, owing to polarization and the deposition of the salts in the solution. This fluctuation is most marked in batteries where the action is very energetic. Small single cells, especially the zinc-carbon batteries, lose much of their power during a long operation. The popular notion that large cells have a therapeutic advantage over small cells by sending a larger quantity of electricity through the body is, in the light of Ohm's law, as well as in the light of experience, erroneous.

Thirdly. For the electro-chemic decomposition of water, salts, and the human body (electrolysis), a considerable number of cells of medium size, neither very large nor very small, and in which the chemic action is powerful, are required.

The resistance of the limited portion of the human body usually submitted to electrolytic operation is great, though not so great as that of the whole body; and as we have seen, before a great resistance, very large cells give no more current in a given time than cells of moderate size. If the cells are too small, however, they will soon become exhausted. The resistance of the skin is very great, but in electrolysis the needles go beneath the skin, and are placed near each other. The resistance is very much less than in external applications when the electrodes are far apart; hence it is an advantage in electrolysis to have cells of good size that do not quickly polarize.

Fourthly. When a short platinum wire in a short circuit is to be heated, as in galvano-cautery operations, a very few large cells or a single very large cell is preferable to a large number of small cells.

This fact has long been practically recognized, and all the batteries for galvano-cautery operations are constructed on this principle. The reason for this is not so well understood. Ohm's law gives us the explanation.

Platinum wire, though it resists the current very powerfully as compared with silver or copper wire, yet offers a very small resistance as compared with water or the human body, or very long wire of any kind. Hence, in the galvano-cautery instruments, the external resistance is small, being not very much greater than the internal resistance of the batteries, perhaps not so great. Now, before a large external resistance—the human body, or very long coils of wires—the surface of the elements is used to the best advantage when arranged in small cells; before a small resistance, the surface of the elements is used at the best advantage when arranged in a few large cells, or, if the external resistance be very slight indeed, a single large cell will be better; for we have previously shown that in a short circuit ten cells give as much current as a great number of cells.

Let us suppose 100 small cells; let each cell have an electro-motive force of 1.5 volts and a resistance of 2 ohms. Let there be enclosed in a circuit the human body, or a very long coil of fine wire, that gives a resistance of 5,000 ohms. Then, according to Ohm's law, we have the following fraction:

$$\frac{1.5}{2} \times \frac{100}{100} = \frac{150}{200 + 5000} = \frac{150}{5200} = \frac{3}{104} \text{ ampere.}$$

which represents the current that flows through the circuit. Suppose now one cell of the same character, but very much larger, sends a current in a short circuit—through a short platinum wire, such as is used in the galvano-cautery for cauterizing surfaces. Suppose the external resistance of this short circuit be 1 ohm. The electro-motive force of the large cell is no more than that of the small cell; the internal resistance of the battery is very much less, for, as we have seen, the resistance diminishes as the surface increases. For convenience' sake we will suppose the internal resistance of the large to be $\frac{1}{10}$ that of the small cell—that is, .2. Now, dividing the electro-motive force by the resistance, according to Ohm's law we have this result:

$$\frac{1.5}{.2 + 1} = \frac{1.5}{1.2} = 1.25 \text{ amperes.}$$

the current that flows through the circuit, many times as much as with 100 small cells.

Suppose now this one large cell be connected by a long and fine platinum wire, such as is used in the removal of tumors by galvano-cautery operations. The resistance will of course be greater, for two reasons, because the wire is longer and because it is finer; for the law is, the less the surface or section the greater the resistance.

Suppose the resistance be 2 ohms. Dividing the electro-motive force by the resistance, we have:

$$\frac{1.5}{.2 + 2} = \frac{1.5}{2.2} = \frac{68}{100} \text{ ampere.}$$

that is, one-half the current that there was when a short platinum wire was in the circuit. Very likely this would not be enough to heat the wire and keep it hot during a long operation. This law comes to our rescue, and helps us out of this as of so many other difficulties. Cut up the one large cell into two cells, and interpose the long fine platinum wire in the circuit. The electro-motive force will be doubled, the external resistance will be the same; but the internal resistance will be greater because the surface is diminished.

Dividing the electro-motive force by the resistance, our fraction stands thus:

$$\frac{1.5}{.5} \times 2 = \frac{3}{1 + 2} = \frac{3}{3} = \text{one ampere.}$$

which is nearly double the current sent through the long wire by a single cell. Thus is explained the fact that the best galvano-cautery batteries are arranged so as to be thrown into one large cell, or cut up into several cells, according as a short or long wire is to be heated.

It has been found by experiment that the heat developed by the current in any wire is proportioned to the squares of the quantity of electricity that flows through it.

This is demonstrated by passing a current through platinum wires in a bottle of alcohol. The heat is communicated to the alcohol, and the thermometer shows the temperature. It is found if a current of a certain strength raises the temperature 10°, a current of twice that strength will raise it 40°.

Again, it is found by experiment that the heat developed by the current in any wire is proportioned to the resistance of the wire.

This is demonstrated with the arrangement just described, by inserting a rheostat whose resistances are known, so as to keep the current strength constant at a fixed point, and then inserting platinum wires of different lengths into the bottle.

From all this it follows that batteries for galvano-cautery should have large surfaces and a small number of cells, and that they should be arranged so that the surface may be used as one or two cells, or cut up into four or six, according as short or long wires are to be heated.

Fifthly. It follows that the dose of an electric application cannot be accurately described by stating the number of cells and the length of the sitting.

This conclusion is an important one, and for want of a knowledge of it electro-therapeutists continually blunder.

Supposing now that we are treating a patient locally or centrally by the galvanic current, and we desire to transfer the patient to another physician. We inform the physician to whom the transfer is made that we are treating the patient with ten cells for ten minutes, and we desire that he should continue to give the same dose. In the light of Ohm's law, let us see what such instructions are really worth. The quantity of electricity that passes through the patient in a minute is equivalent to the electro-motive force divided by the resistance; multiply the quotient thus obtained by ten, and we have the dose of electricity that the patient receives in ten minutes. If, now, all the factors that determine the electro-motive force and the external and internal resistance were constant and were accurately known, and if they were the same for all batteries and all modes of application, then the dose thus ordered would be a mathematical one, and could be mathematically followed. No forms of error are so erroneous or so illusory as those that approach us under cover of facts and figures. In our very attempt to be accurate we stumble into gross inaccuracy. Had we left the whole matter to the judgment of the physician, with some general suggestions as to the susceptibility of the patient, we should have come far nearer the truth, as will be apparent by the following considerations:

The electro-motive force varies in different batteries, and in the same battery at different times. Grove's battery, for example, has four times the electro-motive force of Smee's battery in action, and twice the electro-motive for e of zinc and copper, or Daniell's battery. Then, again, the electro-motive force will in some batteries fall off during an application; and in all batteries, however constructed, the electro-motive force varies at different times.

But the electro-motive force is constancy itself in comparison with the variations of the internal and external resistances. Beginning with the internal resistance, we find that for a Grove's cell, containing one pint of liquid, it is very small, less than 0.5 of an ohm; for a Daniell's cell 1 to 5 ohms, and for a Smee's cell less than 1 ohm. The internal resistance varies with the size and shape of the cell, the distance of the plates from each other, and with the length of time that the battery is in action. Even if the electro-motive force and external resistance were accurate and constant, the variations in the internal resistance would be sufficient to vitiate all attempts at prescribing electricity by the number of cells.

But it is in the external resistance that we find the greatest variation, uncertainty, and inconstancy in applications of electricity to the human body. The external resistance depends on the following factors:

1st. The size and construction of the wires that connect the battery with the electrodes. The larger the section the less the resistance, and, therefore, large wires will conduct more than small ones. A certain conventional size is manufactured by each instrument-maker, but the sizes vary with different makers.

2d. The size and shape of the electrode. Up to a certain point, varying with the number of cells, a large, broad electrode will conduct more than a small and narrow one. A metallic electrode conducts very much better than a sponge; flannel conducts much better than sponge, but worse than metal. The difference in the conducting power of metal, sponge, and flannel is great. A current which is painful when applied by a metal, and is quite perceptible when applied by a flannel or chamois, is not felt at all when applied by a sponge. The painfulness of an application, it is true, does not depend on the amount of electricity that passes, but is also modified by the extent to which the current is diffused. This would depend on the action of the electrode, and therefore an electrode of sculptor's clay, which so accurately adapts itself to every inequality of surface, is less irritating than almost any other form.

3d. The quantity and quality of the liquid used to moisten the electrodes. Electrodes that are perfectly dry conduct but little, at least with currents of the tension used in electro-therapeutics. Electrodes that are wet with warm water conduct better than those that are wet with cold water; and those that are wet with warm salt water conduct best of all. The difference in the conductivity of a sponge wet with simple cold water and one wet with warm salt water is so great that a current which is not felt when applied by the former becomes unbearable when applied by the latter.

4th. The amount of pressure that is used on the electrodes. If the wet sponge is lightly pressed it conducts but little, and its conductivity increases with the pressure. Firm pressure moistens the skin more thoroughly, and thus increases its conductivity, and at the same time it brings into coaptation all parts of the sponge, so that it becomes well saturated.

5th. The position and extent of the body included between the electrodes. This factor is a most important one, and it has been unaccountably overlooked in all discussions on this subject. The difference in the conductivity of the bones and soft tissues is all the difference between twenty and one, and in all parts the conductivity is modified by age, by temperament, and by disease. The resistance of the whole body, from one hand to the other through the shoulders, is about seven or eight times the resistance of the Atlantic cable, and the resistance of the whole length of the body, from the head and shoulders to the feet, is probably greater than that. But the resistance of any limited portion of the body, as the head, or spine, or cervical sympathetic and pneumogastric, or individual muscles or nerves, must be only a fractional part of the resistance of the whole body. Other conditions being the same, the nearer the electrodes are to each other the less the resistance.

6th. The length of the application. When the galvanic current is first applied to the body by wet sponges, but little sensation is experienced on the skin; but in the course of a few seconds a burning pain is felt, that increases with the length of the application. This is explained in part by the chemic changes that take place, and in part by the fact that as the skin becomes more and more moistened by the pressure of the wet sponge, and the skin under the electrode becomes more and more congested, the resistance is diminished. Consequently, toward the close of even a very short application, more electricity passes, all other conditions being the same, than at the beginning. On this account it frequently becomes necessary to reduce the number of cells during the sitting, especially when the electrodes are kept all the time on one spot. Thus it becomes clear that any attempt to prescribe the dose of electricity by the number of cells, in ordinary external applications to the body, must fail of its object.

Although the above statements have reference only to the galvanic current, they just as truly apply to the faradic; for induced as well as galvanic electricity is subject to the law of Ohm. One difference, however, should be noted, that on account of the slighter chemic action of the faradic current the resistance of the skin beneath the electrodes does not diminish with the length of the application.

Finally, Ohm's law explains the fact of observation, that when the poles of a galvanic battery are metallically connected, the chemic action in the battery is greatly increased and the plates rapidly destroyed. The metals, being better conductors than the body, conduct much greater quantity of electricity; and as the potential quantity of electricity that any battery is capable of generating is limited, then when the resistance between the poles is least the action must be strongest, and the metals the most rapidly consumed. Neglect in this regard causes the premature destruction of many batteries.

ELECTRO-PHYSIOLOGY.

ELECTRO-PHYSIOLOGY.

CHAPTER I.

RELATION OF ELECTRO-PHYSIOLOGY TO ELECTRO-THERAPEUTICS —ANIMAL ELECTRICITY.

Electro-physiology is the science which treats both of the laws of animal electricity and also of the phenomena produced by the action of electricity on the body in health. We propose to present this subject as compactly as possible, and consequently shall speak only of those facts that are necessary for a true appreciation of the science, and chiefly of those that, directly or indirectly, have a practical bearing on electro-therapeutics.

Electro-Physiology Largely Studied by Experiments on the Living Human Subject.—An advantage of great import to electro-physiology, and one that especially commends it to the electro-therapeutist, is that it is largely based on experiments made on the living human subject. True enough, thousands of frogs have given up their lives in the electro-physiologic laboratory, and dogs and cats, rabbits and guinea-pigs, rats, and monkeys even, have been subjected to electric tests while living, in health and uninjured, while dying, and when dead; but some of the most interesting and suggestive phenomena of this science, those which have the nearest practical relation to electro-therapeutics, can be best studied on the living human subject, and without injuring the subject experimented on. This is the supreme advantage of the study of the physiologic action of electricity over the study of the physiologic action of the majority of drugs. The objection so often made against experiments made with medicines on inferior animals, that they do not teach the action of such medicines on the human body in disease, cannot, therefore, apply to electro-physiology, except to a limited degree.

Not a few of the physiologic reactions of the human body to electricity can be studied while making therapeutic applications. The reaction of voluntary muscles, of the motor and sensory nerves, of some of the nerves of special sense, to electricity, and the general effects of electricity on nutrition, are taught us every time we electrize a patient by any of the familiar methods of application. Electro-physiology and electro-therapeutics thus go hand in hand.

The Localization of Electricity in the Body an Advantage in Studying its Physiologic Effect.—The drugs with which we experiment on animals, in order to learn their physiologic action, are usually absorbed and carried through the whole system. If they select any organ on which to expend their force in preference to other parts, it is by virtue of their inherent affinity for such organ, and not from any power in the experimenter to confine them there. But electricity can, to a certain extent, be localized in a muscle or nerve, or in some special organ; thus its effects can be studied with greater precision and certainty than the effects of drugs internally administered. Thus the physiologic action of electricity has a specially practical bearing on its therapeutic action.

Animal Electricity is the Electricity that Exists in Animal Bodies. Electric Fishes.—The most remarkable display of animal electricity appears in certain varieties of fishes. At a very early period it was known that a certain flat fish had not only the power, when touched, to give forth shocks, but could impart to other bodies, for some distance through the water, a benumbing influence. This phenomenon was first proved by actual experiment to be of an electric nature as early as 1773; and soon after, by means of a number of Leyden jars, connecting with a disk of leather or wood, either side of which was covered by tinfoil, an artificial torpedo was constructed. The subject of animal electricity is one of great scientific interest, and may in time become of direct practical value to electro-therapeutics. This peculiar power is possessed only by a small number of fishes, the best known of which are the torpedo or electric ray, the gymnotus or electric eel, and the electric shad.

This development of electricity does not take place in all parts of the fish, but is confined to a peculiar expansion of the nervous system, called the electric organ. The nerves constituting the electric organs of the torpedo and gymnotus are of great size. Those of the former consist of three principal trunks, and arise from the cerebro-spinal system; while the nerves composing the electric organs of the latter are derived from the spinal cord alone. As stated above, the phenomena produced by these fishes are similar to those which are obtained from electricity that is artificially generated.

If electric fishes are touched with the hand, a shock is perceived, while if glass, resin, or any other non-conductor is intervened, no effect is produced.

Sparks may be drawn from them in the same way that they are drawn from other bodies that are artificially charged with electricity. The current obtained from them will magnetize steel needles, decompose water, and if the needle of a galvanometer be brought into the circuit it will immediately suffer deflection, so that the direction of the current may be readily determined.

The electric force of the fish is much weaker after it has exerted its power a number of times in quick succession, and it requires rest and nourishment to enable it to recover its normal vigor.

History of the Discovery of Electricity in the Body of Man and Other Animals.—We have already seen that Galvani discovered in 1786 that muscular contraction follows the contact of the nerves and muscles of a frog with a heterogeneous metallic arc. From this observation, and from subsequent study of the subject, Galvani was inclined to believe and to declare that in the tissues of animals there exists a special independent electricity, which he called animal electricity. Although Galvani's conclusions were, as we now know, not entirely logical, yet he stumbled on an important discovery that was destined to be demonstrated and confirmed by other and later observers.

There is such a force as animal electricity, but the experiments of Galvani are explained by contact of dissimilar substances and by the chemic action of the fluids of the body on the metals, and not by the electricity of the body.

Volta's researches have already been given in Electro-Physics.

Humboldt's Researches.—In 1799 Humboldt published a work containing the result of many and curious experiments, the object of which was to show that both Volta and Galvani were right and both wrong; that there was such a thing as animal electricity; that Galvani was in error in regarding it as the only form of electricity that appeared in his experiments; and that Volta was in error in refusing to admit its existence.

Aldini's and Nobili's Researches.—In 1803 a nephew of Galvani, Aldini, published experiments that went to demonstrate the existence of animal electricity. The voltaic pile, however, was a stronger argument against the existence of animal electricity than any experiments could be in its favor, and for these reasons animal electricity was forgotten.

In 1827 M. Nobili, having constructed a very sensitive galvanometer, was enabled, as he supposed, to detect, without doubt, the existence of an electric current in the frog. He observed that when the needle was placed in the circuit it deviated some 30°.

Researches of Matteucci and Du Bois-Reymond.—A few years subsequently, Matteucci turned his attention to this subject; but it was reserved for Du Bois-Reymond to investigate most clearly and most fully, if not most conclusively, the electric properties of the nerves and muscles.

By these two observers it is believed to have been shown, 1st. That currents in every respect like the frog-current of Nobili, are not peculiar to the frog, but are inherent in all animals, warm and cold-blooded—in toads, salamanders, fresh-water crabs, adders, lizards, glowworms, and tortoises, as well as rabbits, guinea-pigs, mice, pigeons, and sparrows. (Du Bois-Reymond.)

2d. That currents are found in nerves as well as muscles, and that both are subject to the same laws. (Du Bois-Reymond.)

3d. That the current usually observed is a muscular current that is produced by the muscles, the nerves acting only as inactive conductors. (Du Bois-Reymond.)

4th. That this muscular current may be upward or downward, and that the current of the whole limb is the resultant of the partial currents of each muscle. (Du Bois-Reymond.)

5th. That these currents do not depend on the contact of heterogeneous tissues, as Volta had believed, for the nerves, muscles, and tendons in their electric relations are homogeneous. (Du Bois-Reymond.)

6th. That electricity is found not only in the muscles and nerves, but also in the brain, spinal cord, and sympathetic—in motor, sensory, and mixed nerves—in a minute section as well as in a large mass of nervous substances—in a small fibril as well as in a large muscle—in the skin, spleen, testicles, kidneys, liver, lungs, and tendons; but not in fasciæ, sheaths of nerves, and sinews.

7th. That animal electricity is capable of decomposing iodide of potassium, and of deflecting the needle of the galvanometer. (Matteucci.)

8th. In the muscles and nerves electricity is in the condition of a closed circuit.

9th. That contraction of muscle is accompanied by an electric discharge resembling that of a torpedo. (Matteucci.)

It was the perusal of the essay of Matteucci that inspired Du Bois-Reymond to undertake those magnificent researches that have given him a name and a fame in the realm of electrology.

He devised special apparatuses for his researches, and handled them with great skill and patience.

Even if many of the conclusions presented are erroneous, they are none the less interesting suggestions, and have prepared the way for those who are now earnestly seeking to discredit his experiments and disprove his statements.

The above conclusions of Du Bois-Reymond were derived from experiments on the nerves of frogs, but electricity is not confined to the lower forms of life, either dead or dying.

Electricity in the Living Man.—In the living man it is believed that cutaneous currents are found. The hand is negative to the elbow, and the palm of the hand is negative to the back. The foot is negative to the chest, and the sole of the foot is negative to the back. The elbow is slightly positive to the chest, and the hand is sometimes negative to the foot, and sometimes the reverse.

These cutaneous currents are quite strong and uniform. They are to be distinguished from the thermo-electric currents that are observed when two symmetrical parts are heated.

A finger at the temperature of 32° is positive to one at 90°, and a finger at 60° is feebly positive to one at 80°, and strongly positive to one at 180°. The cutaneous currents are also to be distinguished from currents that arise from dissimilar immersion, dissimilar sweating, and shielding of the body.

Currents of electricity have been found in the urethra and bladder of the rabbit, the intestines, the spleen, the testicles, the tendons, and the oviduct of the frog, and the iris of birds.

All these currents resemble the ordinary muscular currents, in that the outer and inner surfaces have opposite electricities.

The currents of the nerves and muscles are very much stronger than those of other tissues.*

Dr. C. B. Radcliffe takes a radically different view of animal electricity. His conclusions, briefly summarized, are as follows:

1. The sheaths of the fibres of nerve and muscle during rest are charged with electricity like Leyden jars. He believes it probable, though not entirely demonstrable, that the sheaths of the fibres conduct electricity so feebly that they are practically non-conductors and are di-electric.

This charge is brought about by the development of electricity, either positive or negative, through oxidation, or some form of chemic action, on the outside of the sheaths of the fibres, which electricity induces, through the di-electric sheath, an opposite electricity from the inside of the sheaths, after the manner of the Leyden jar. Electricity which exists in the nerves and muscles during rest is in a static condition, and not in dynamic or current state.

The nerve-current and muscle-current are purely incidental phenomena, resulting from applying the electrodes to points of unequal electric tension.

2. That the passage of a nerve or muscle from a state of rest to a state of action is accompanied by a discharge similar to that of a torpedo. The arguments in favor of this view are, that the anatomical and physiological apparatus of the torpedo closely resembles the muscular apparatus of all animals; that the nerve-current nearly disappears from the nerve, and the muscle-current from the muscle, when nerve and muscle pass from rest into action; and, finally, that the phenomena of induced or secondary contraction cannot otherwise be explained.

This discharge takes place between the sheaths of the fibres, which are very elastic, and are capable of being elongated during rest by the mutual attraction of the opposite electricities with which they are charged.

3. That when a nerve or muscle passes from action to rest it resumes

* "Dynamics of Nerves and Muscles," London, 1871.

its condition of charge. Elongation, therefore, is the result of charge and contraction of discharge.

This point is illustrated by the following experiment:

A narrow band of rubber is wound on both surfaces very near the edge with gold-leaf, so that it can be charged or discharged with electricity like a Leyden jar. By a simple arrangement of a grooved wheel and an apparatus that multiplies and records the movements, it can be shown that when the band is charged by a few turns of a frictional machine, it elongates, and when the charge is discharged it contracts. It is believed that the muscle behaves in precisely this manner. If nerves are not affected in the same way, it is because their fibres are not sufficiently elastic.

4. That the blood keeps up the natural charge of electricity in nerve and muscle.

The acceptance of this view explains many interesting facts in pathology. It explains the fact that diseases that are accompanied by a deficiency in the nerve-currents, as neuralgia, spinal irritation, hysteria, tetanus, epilepsy, usually manifest themselves by morbid activity, by increased and unnatural movements of muscles and nerves.

Active inflammations, when there is increase of blood, are not usually accompanied by excessive muscular or nervous action.

Apparatus for Studying Animal Electricity.—In a practical work of this kind it is not necessary nor proper to enter into elaborate detail of all the experimental premises by which Matteucci, Du Bois-Reymond, Pflüger, and others have made their discoveries. A very brief description of the apparatus of Du Bois-Reymond may possibly be of interest.

He employed a very delicate galvanometer, the distinctive features of which were, first, the astatic needles were constructed and arranged with great care; and, secondly, the wire around them was very long, and of from 4,000 to 24,000 convolutions. A multiplier of this sort will indicate the presence of exceedingly feeble currents. The wires of the multiplier are connected with carefully cleaned and prepared flat new plates dipped in vessels of zinc, containing sulphate of zinc to prevent polarization. Two cushions, as they are called, made of layers of blotting-paper soaked in a solution of sulphate of zinc, are laid in the edge of each vessel, with their ends in the liquid. The whole is enclosed in a moist chamber. In order to protect any tissue, it is placed in connection with the two cushions in various positions; then, if there be any current, the deflection is seen in the needle of the multiplier.

When two symmetrical parts of the longitudinal or transverse section of a nerve are applied to the cushions, no deflection is seen; when two dissymmetrical parts of the longitudinal section are placed on the cushions, the needle deflects 6° or 7°. When the longitudinal section of the nerve on one side touches one cushion, and the transverse section touches the other side, the needle deflects 15° to 30°.

Instead of the galvanometer multiplier we may use the rheoscopic frog, which may give some results; but it has the disadvantage that it loses its irritability, and that it contracts only when the current is closed or broken.

Experiments of Trowbridge.—We have given a full and varied presentation of the leading conclusions of Du Bois-Reymond and others, and have described, in a very general way, the best method of performing the experiments on which his conclusions are based.

We have done this in justice to a name that is greatly honored in science, in justice to the name that has made an era in physiology, and to prepare the student for an intelligent understanding of the experiments that seem to overthrow these views of Du Bois-Reymond that have been so widely accepted.

It has always appeared to us that in the experiments of all electro-physiologists, the later as well as the earlier school, there were chances for great error, and have been surprised that their conclusions have been accepted with so little reservation.

Bearing in mind that all chemic action, however slight, is probably accompanied by the generation of electricity, it is surely not irrational to suspect that the conclusions from careful experiments of Du Bois-Reymond and others might be in some, if not in all cases, modified by chemic action between the animal tissues and the cushions of the galvanometer, however skilfully these were protected.

Among the physicists at least, the theories of Du Bois-Reymond have been, on the whole, losing ground, and probably on account of the considerations that are above presented.

Prof. John Trowbridge, of Harvard College, has made a series of researches that seem to cast grave doubts on the interesting and hitherto accepted conclusions of Du Bois-Reymond in regard to animal electricity.

This physicist, starting out on the face of the accepted fact that two liquids of dissimilar chemic character, separated by a porous partition, give rise to a current of electricity, has made experiments with an apparatus similar to that employed by Du Bois-Reymond in his researches on animal electricity. Instead, however, of placing a piece of muscle or nerve on the cushions, he used a series of artificial muscles. These artificial muscles were made of glass-tubes covered by porous partitions, and filled with the different liquids, such as—

Undistilled water,
Weak solution of salt in distilled water,
Solution of different salts of iron,
Blood,
Acidulated water.

Placing the artificial muscle thus prepared in the position where the natural muscle is placed in Du Bois-Reymond's experiments, he found that each liquid caused a deflection of the needle of the galvanometer.

There is no question, in the opinion of Professor Trowbridge, that the currents that caused these deflections of the needle arose from the actions of the fluids in the tubes on the saline solution of the cushion and the protecting guard. This view is confirmed by the fact that when the artificial muscles were filled with distilled water, there was no deflection of the needle observed; but when undistilled water or the other fluids mentioned were used, the needle of the galvanometer deflected so far as in some cases to throw the spot of light off the scale.* Professor Trowbridge exercised the same precautions as are found necessary by electro-physiologists in obtaining the so-called muscular currents. He argues that the behavior of the artificial muscle must be similar to that of a natural muscle placed on the cushions; and he states further, that when we use the natural muscle, containing fresh and chemically active blood, separated by its sheath from the clay guards of the cushions, an electric action must take place between the fluids of the muscle and the saline solutions in the connecting apparatus, which action cannot well be distinguished from the so-called muscular current.†

In order to avoid every possible source of error in these experiments, Professor Trowbridge not only tried distilled water in the artificial muscles, instead of undistilled water and the different solutions, but also tried the mere contact of the bladder membrane-partition without any fluid, and in neither case was any current produced. He employed a vessel shaped like the letter U, opened at the bend, and covered at the ends by a membrane. Into the two limbs of the tube he injected fluids of different kinds. When the vessel was filled with a fluid that was homogeneous, and the ends of the tube brought in contact with the cushions, the needle of the galvanometer was deflected. When the points of contact were reversed, the direction of the needle was reversed. That mere contact of the tubes with the cushions did not cause the deflection of the needle, was shown by the fact that when no fluids were in the tube there was no deflection. That the direction of the current was through the U-shaped tube, and not from its extremities to the galvanometer and back, was proved by the fact that when the section of one of the limbs of the U-shaped tube was constricted, the deflection of the needle was reduced, and when the constriction was complete there was no deflection.

The conclusion to which Professor Trowbridge arrives from these experiments, which have been repeated at various times, is "that when the cushions of the galvanometer are connected by a membranous sac containing fluids, or animal tissue saturated with fluid, an endosmotic action takes place, accompanied by galvanic action; and that this galvanic action is

* Thomson's reflecting galvanometer and new quadrant-electrometer were used in these experiments.

† "On the Electro-motive Action of Liquids separated by Membranes." American Journal of Science and Arts, vol. iii.

determined by the difference of endosmotic action at various points of the enclosing membrane."*

When, therefore, a muscle is placed on the cushions of the galvanometer, its transverse section on one pad and its longitudinal section on the other, endosmose takes place, which is different at different points, and the galvanic current that appears is probably caused by this difference of endosmotic action and not by the so-called muscular current. Then granting that a muscular current exists, it must suffer important modifications in strength and direction through this endosmotic action. If the muscular current does not exist, this endosmotic action, with the accompanying galvanic action, will account for the deflection of the needle of the galvanometer that had been supposed to be due to the muscular current.

Trowbridge thinks that the phenomena noticed by Du Bois-Reymond arise from differences in the chemic nature of different portions of the muscle, although Du Bois-Reymond contends that such chemic difference does not exist, and that the tissue is homogeneous from a chemic point of view.

The papers of Burdon Sanderson and Gotch,† and the later researches of Fritsch,‡ of Berlin, may be consulted with advantage by those who are interested in the subject of animal electricity.

* Proceedings of the American Academy of Arts and Sciences, January 9, 1872.

† Journal of Physiology, vol. ix., Nos. 2, 3, and vol. x., No. 4.

‡ Nature, vol. xvii., No. 12.

CHAPTER II.

ELECTROTONOS, ANELECTROTONOS, AND CATELECTROTONOS.

Electrotonos is the peculiar modification of irritability that nerves and muscles undergo when acted upon by a galvanic current.

While the nerve is in the electrotonic state, that part of it not included between the poles will deflect the needle of a delicate galvanometer; and that the deflection then caused is not due to the natural nerve-current, is proved by the fact that it appears when only the surface of the nerve is connected with the galvanometer. It is therefore the electric condition of the nerve caused by the passage of the current through it that deflects the needle. The electrotonic condition not only remains so long as the galvanic current continues to pass, but, if the current be sufficiently powerful, it remains for a limited time after the current ceases to pass.

The electrotonos is more noticed the larger the extent of nerve acted upon, provided the current be sufficiently increased to overcome the increased resistance.

In nerves that are dead, or have lost their irritability, electrotonos cannot be excited at all, or only feebly, and the same is true when the nerve is cut across or tightly bound with a ligature.

The change in the nerve-current depends on the direction of the galvanic current. When the galvanic current flows in the same direction with the nerve-current, the strength of the nerve-current is increased; when the galvanic current flows in a contrary direction, the strength of the nerve-current is diminished.

Electrotonos is greater when the galvanic current flows lengthwise than when it flows across the nerve. It increases, within certain limits, with the increase in the intensity of the current.

Molecular Theory of Anelectrotonos.—Du Bois-Reymond has suggested a theory to account for the phenomena of electrotonos, which has been generally accepted. It is analogous to the theory of magnetism suggested by Coulomb. He supposes that muscles and nerves consist of electric molecules, which have one positive equatorial zone and two negative polar zones, whose axes are parallel to each other, that is, two molecules make one molecule. This is called the peri-polar arrangement. In a magnet, each individual molecule manifests the same phenomena as the entire magnet: each molecule is indeed a magnet in miniature. In like manner, each molecule of the nerve or muscle manifests the same phenomena as the entire nerve or muscle. These peri-polar molecules are enclosed by a moist covering.

Du Bois-Reymond further supposes that each peri-polar molecule may be divided into a group of di-polar molecules—where the positive hemispheres are turned toward each other—without changing their electric properties. This is called the di-polar arrangement. If a number of such molecules are brought under the influence of a galvanic current, their positive zones will turn toward the negative pole, and the negative toward the

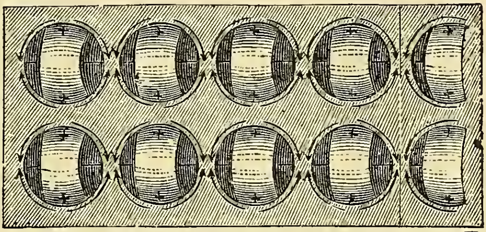

FIG. 38.—Peri-polar Arrangement of Electro-Motor Molecules. L S, Longitudinal section; T S, transverse section; P, parelectronomic layer.

positive; one of the molecules (3) turning 180° on its axis. The arrangement will be as above. From its resemblance to the voltaic pile it is called the pile-like arrangement.

This pile-like arrangement of the molecules not only takes place between the electrodes, but also beyond them into the extra-polar region.

Du Bois-Reymond has illustrated these phenomena on molecules made of zinc and copper.

From these experiments Du Bois-Reymond concluded, first, that the nerve is always in the condition of a closed circuit, since electric currents are produced by the connection of layers surrounding the molecules with their molecules; and secondly, that the current obtained from an animal, as indicated by the galvanometer, is only a small portion of the entire current.

The galvanic current that produces the electrotonic condition is called the polarizing current. The portion between the poles is called intra-polar; beyond and outside of the poles, extra-polar. Electrotonos is ascending when it proceeds from the muscle to the nerve; descending when it proceeds from the nerve to the muscle.

Anelectrotonos and Catelectrotonos.—Anelectrotonos is a ondition of diminished irritability which takes place at the positive electrode. Catelectrotonos is a condition of increased irritability which takes place at the negative electrode. At some point between the electrodes the irritability of the nerve is unchanged. The conditions of anelectrotonos and catelectrotonos are found not only between the poles, but also in the other portions of the nerve, in the extra-polar portion.

The portion between the poles and near the negative pole, together with the portion beyond the negative pole, is in a state of catelectrotonos, with increased irritability. The portion between the poles and near the positive pole, together with the portion beyond the positive pole, is in a state of anelectrotonos, with diminished irritability.

The extra-polar catelectrotonos depends on the length of the nerve

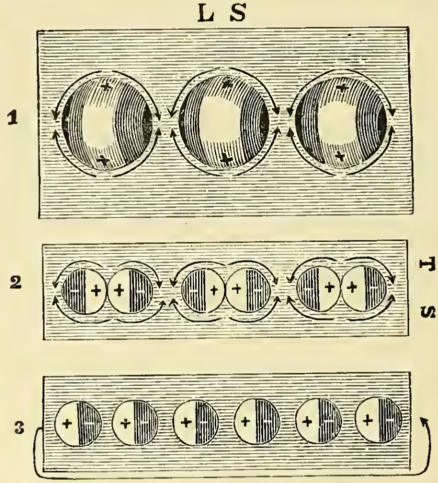

FIG. 39.—L S, Longitudinal Section. T S, Transverse Section. 1, Peri-polar arrangement of electro-motor molecules; 2, di-polar arrangement of electro-motor molecules: 3 pile-like arrangement of electro-motor molecules, caused by the action of the galvanic current.

between the poles, and the strength of the current, up to a certain limit. The strength of the extra-polar anelectrotonos is proportioned to its distance from the poles, being greatest near the intra-polar portion. The extra-polar catelectrotonos, both ascending and descending, is in a state of increased irritability. The extra-polar anelectrotonos, both ascending and descending, is in a state of diminished irritability.

Neutral Point.—Between the poles there is a point where the irritability is not changed; there anelectrotonos meets catelectrotonos. This is called the neutral point. The relative position of this depends on the strength of the polarizing current. Where the strength of the current is medium, the neutral point is about midway between the poles. Where the current is weak, the neutral point is nearer the positive pole. Where it is strong, it is near the negative pole.

Negative Variation.—When a current frequently interrupted is applied to an irritable nerve, it causes the nerve-current to diminish in strength, and finally utterly destroys it. This fact is demonstrated by the galvanometer.

The same phenomena are caused to a less degree by chemic or mechanical stimulation of nerve. Negative variation has been explained by the theory that the peri-polar molecules in the nerve change their arrangement, so that their electro-motor power is diminished. The negative variation of the current has been studied by Bernstein,* and later by Burdon Sanderson.† Bernstein regards all the electric phenomena of the nerve as undulatory movements, and has mathematically estimated the length of the waves in nerve and muscle. Cyon, in confirmation, has shown that the degree of the variation is directly proportioned to the number of interruptions in the exciting current.

Effects of Electrotonos in Diminished Conductivity.—The power of a nerve to conduct irritability is more or less modified by the condition of electrotonos. The portion of the nerve near the positive pole, which is in a condition of anelectrotonos, has its conductibility diminished; the portion of the nerve near the negative pole, which is in a condition of catelectrotonos, has its conductibility increased. If the current be sufficiently strong, the power of the nerve to conduct impressions may be nearly or entirely destroyed.

Effects of Electrotonos after the Breaking of the Galvanic (Polarizing) Current.—One of the effects of the electrotonos is the irritation which is caused by the passing away of the anelectrotonos. This irritation, which appears at the positive pole, is shown either by a contraction or by a tetanic condition.

Positive Modification and Negative Modification.—The nerve which is in a condition of catelectrotonos at the negative pole is greatly modified by the breaking of the polarizing current. Its irritability is thereby diminished. This diminution of irritability is called the "negative modification." At the positive pole in the catelectrotonic region, an increase of irritability, or positive modification, appears on breaking the current. This increase and diminution of irritability continue for some time after the polarizing current is broken.

Physiologic Effects of Current Direction.—Although it is impossible to confine the current to the trunk of a nerve, yet it is not, according to our experimental researches, incorrect to speak of ascending and descending currents, as has been so often asserted. On the contrary, experiment clearly demonstrates that the irritability of a part is influenced not alone by polar action but by current direction as well. If an electrode is constructed so as to eliminate the action of either pole at will, one can readily study the effects of current direction, and will find, as have we in repeated experiments, that the changes of irritability caused by changes in the direction of the current without regard to polar action are very marked in degree.

Restoration of Irritability.—A very important effect of electrotonos is a

* "Untersuchungen über den Erregungsvorgang im Nerven- und Muskelsysteme," 1871.

† Centralblatt für Physiologie, 1890, Band iv., S. 185.

restoration of irritability in a nerve. It has been proved, both by experience and by experiments, that nerves which from any cause have lost their irritability to the faradic current sometimes regain it after an application of the galvanic. It has been shown by long experience that, in cases of paralysis, when the faradic current at first fails to produce contractions, the application of the galvanic may not only readily produce contractions, but may also produce such a change in the irritability of the paralyzed parts as to cause them to regain their lost irritability to the faradic current. (See Electro-Therapeutics.)

Electrotonos of Muscle.—A muscle, like a nerve, may be put in the condition of electrotonos; the changes of irritability that accompany this condition are confined to the portion of muscle through which the current flows. The subsequent effects, after the polarizing current is broken, are also limited to the portion through which the current passes.

It is logically probable, also, that not only the motor-nerves, but also all parts of the nervous system—central and peripheral—are capable of exhibiting the phenomena of modified irritability under the galvanic current.

Theory of Anelectrotonos and Catelectrotonos.—That the galvanic current in its passage through the nerve diminishes the irritability of that nerve in the region of the positive pole, and increases its irritability in the region of the negative pole, may be explained by the purely physical effects of the currents in the tissue.

We have seen that in electrolysis acids go to the positive and alkalies to the negative pole; now it is a fact of physiology that acids diminish the irritability of nerves, while alkalies increase it. Anelectrotonos and catelectrotonos may therefore be caused by acids at the positive and alkalies at the negative pole.

This explanation is rendered probable by two facts: first, that anelectrotonos and catelectrotonos are not produced by the secondary faradic current, which has no marked chemic action; and secondly, that very feeble and instantaneous passages of the galvanic current produce electrolytic effects.

Pflüger's Contraction-Law.—The law of contraction, as derived by Pflüger from experiments on the frog, is thus formulated: The nerve is excited by the appearance of catelectrotonos and the disappearance of anelectrotonos, but not by the appearance of anelectronos or the disappearance of catelectrotonos. This law is considered of great scientific as well as practical value.

Electrotonos in the Living Man.—The subject of electrotonos in the living man has been studied by Eulenburg, Samt, Von Bezold, Brenner, Erb, Brückner, Runge, and Filehne, but most successfully by Cyon.

Cyon,* by a series of elaborate and careful experiments, has shown

* "Principes d'Electrothérapie," Paris, 1873, p. 130 *et seq.*

that the contraction-law of Pflüger, as established on the frog preparation, applies also to the living human subject.

He has shown that, after closing the circuit, the irritability is increased near the negative pole; that this condition of catelectrotonos increases as the current runs up to a certain point; that on breaking the current the negative modification, or condition of diminished irritability, appears for a moment, and then disappears.

Near the positive pole, on the other hand, the irritability is diminished at and after closing the current. On breaking the current there is an increase of irritability, or positive modification, which appears to be greater when the current has been allowed to run a long time.

The experiments from which Cyon derived these conclusions were made on the ulnar nerve, and with great care to avoid error. It will be seen that the results correspond with the results of Pflüger's experiments on the frog, and confirm them. Cyon found, however, that these results were not uniform in all persons, but were modified more or less by temperament and disease.

Practical Bearings of the Laws of Electrotonos.—While the laws of electrotonos do not account for all the therapeutic action of the galvanic current, they are, nevertheless, of great value, and help to explain the practical differences observed in the action of the two poles. In a carefully prepared article, however, by De Watteville,* the conclusion is reached "that a therapeutic system, built on the opposite anelectrotonic and catelectrotonic effects, rests upon an imaginary basis. . . . Both are stimulants, if 'stimulation' there be, the kathode more than the anode."

* "Conditions of the Unipolar Stimulation," etc. Brain, part ix.

CHAPTER III.

ACTION OF ELECTRICITY ON THE SKIN.

In regard to the study of the action of electricity on the body in health, it is necessary to make the preliminary remark that many of the experiments that have been made and published, and widely quoted in this department, have but little scientific value, and cannot be regarded as in any sense authoritative. The reasons for the uncertainty pertaining to the reported experiments are manifold:

1. The distinction between the currents has not been observed. Not only have the faradic and the galvanic currents been constantly confounded, but the subdivisions of the faradic current—currents of low and high tension—have been vaguely commingled. Many observers speak of galvanization when they mean faradization, and *vice versa*, and not a few apply both terms to the use of the same current.

2. Allowance has not been made for the differential action of strong, medium, and feeble currents, or of long and short applications. The difference in the physiologic effect of a large and small dose of opium, strychnine, belladonna, or ergot, or any other powerful remedy whatsoever, is enormous. When a small dose has no perceptible effect, a large dose may throw into profound sleep, or into violent convulsions, that lead to death. In speaking of the physiologic action of drugs of any kind, the dose is always mentioned, and any experiment with drugs, on man or animals, when the dose is not known or mentioned, has little value in science. Similarly also in electro-therapeutics, we find in every-day experience that the difference in the effects of a mild and short, and a severe and long, application, is only the difference between making a patient infinitely better or infinitely worse.

When, therefore, we read that galvanization of the sympathetic or pneumogastric produces such and such effects, we really get no precise knowledge whatsoever.

3. The differential susceptibility of man and animals has not been duly considered. Experiments with electricity performed on the lower animals, as frogs, dogs, cats, horses, rabbits, cows, guinea-pigs, etc., do not always afford a safe basis for generalization in regard to the effects of electricity on man, and especially on man in a state of civilization. In their susceptibility to the electric stimulus, and in the length of time that they retain their irritability after death, there is a great difference in

animals; between animals and civilized man this difference must be very great.

In proportion as the organization of man is more complex than that of the lower animals, in that proportion will the physiologic reactions of the human body to the electric current, or indeed to any other influence, be more complex and uncertain, and more liable to deviations and modifications than the physiologic reactions of the inferior forms of life to which we are supposed to be related. Conclusions in electro-physiology, derived solely from experiments on animals, have the great merit of simplicity; but when applied to the far higher and more complex organization of man, and especially of civilized man, with his excessively sensitive system of nerves, they are apt to lead into serious error.

4. Individual idiosyncrasies have not been properly considered. The action of medicines varies with the temperament to such a degree as to make necessary great caution in rushing to generalizations from experiments on one or two persons. Applications of electricity, faradic or galvanic, to the cervical sympathetic, similar in length and strength, may cause in one individual symptoms of cerebral congestion, in another symptoms of cerebral anæmia, and in another its effects may be purely negative. In one individual the effects of such application may be felt at once, in another an hour or two after the application, in another not until the following day.

There is a great difference in the average susceptibility of different nationalities and of the higher and lower orders of society, with occasional exceptions both ways; the tough, coarse-fibred laboring classes are much less susceptible to electricity, just as they are much less susceptible to drugs, than the delicate, finely organized, brain-working classes.

5. The action of electricity on the body in health may be learned, in part at least, by studying its action in disease.

"Pathology," Allbutt well says, "is but the shady side of physiology." To draw the line precisely where health ends and disease begins, is oftentimes beyond the power of mortal man. Of the deep darkness of the midnight hour any child is conscious, and even the birds discern the approach of evening; but what physicist so keen as to tell the precise moment when the late afternoon begins to fade into the early twilight?

It is because physiology and pathology thus run into each other, that observations on pathologic states may be of great service to physiology. Experiments made with electricity on patients more or less diseased have helped, as we shall see, to solve some of the problems of electro-physiology. Certain pathologic states render the nerves unusually impressible to electricity in degree, though in the same way as in health, and thus are of great value to the electro-physiologic experimenter.

The above considerations explain in part the opposite and inconsistent as well as fragmentary character of electro-physiologic researches, and they should be borne constantly in mind by those who study this and the following chapters, devoted to the action of electricity on the human body in health.

Action of Franklinic Electricity.—When the sparks of frictional electricity are applied to the skin they produce a sensation of pricking, and if the sparks are large the skin becomes red and a papular eruption appears. Applied to the scalp, it causes the hair to stand on end.

Action of the Faradic Current.—If any dry artificial electrode is pressed against the dry skin while a faradic current is passing, the electricity will penetrate but slightly to the deeper tissues, unless the current is very intense, because of the great resistance offered by the skin.

One effect of the faradic current on the skin in this way is to cause a change in the circulation. The change may be either anæmia or hyperæmia. At first there is anæmia. The calibre of the blood-vessels is narrowed, through the action of the current on the vaso-motor nerves. This contraction with anæmia is spasmodic in its character; it lasts but for a time, and in the course of two or three minutes it gives way to hyperæmia. The skin becomes red, and remains so for a short or long time, from several minutes to several hours, according to the strength of the current, the length of the application, and the temperament of the individual.

Another effect of faradizing the skin in this way is pain. This pain is caused by the irritation of the extremities of the sensory nerves.

When the dry hand is substituted for the dry artificial electrode, the surface can be faradized without producing pain. During the latter operation the electricity, acting upon the dry surface of the skin, produces a peculiar cracking or humming sound that may be heard several feet.

An application of a faradic current of ordinary strength is followed by the most marked effects on the skin when it is dry, from the fact that the electricity is mostly confined to the surface of the tissue. A very fine, or, in other words, a rapidly interrupted, faradic current has a more marked effect on the sensory nerves than a coarse, or slowly interrupted, current, and in the treatment of the more common forms of anæsthesia and neuralgia this fact must be considered. The negative pole has a much stronger effect both on the sensory and motor nerves than the positive. Any one can readily distinguish the poles, when held in the hand, by the stronger sensation and more violent muscular contraction which is felt at the negative.

Some parts of the skin are more sensitive to the current than others, from the fact that they are more richly supplied with nerves. The face is especially sensitive at the points where the various branches of the trigeminus issue, and at the line of demarcation of the skin and mucous membrane of the nose and mouth. The relative sensitiveness of different parts of the surface of the body to the faradic current will be discussed in detail in a chapter devoted to that subject in the section on Electro-Therapeutics. A faradic current of moderate strength, when applied to bones that lie very near the surface, produces considerable pain of a peculiar character. This pain is caused on account of the irritation of the sentient nerves of the periosteum. The forehead and the region of the scapula and tibia are especially sensitive to electrization.

It is not supposed that the bone is specifically affected by the electric current. Both the periosteum and the bone, however, may have an increased amount of blood attracted to them by the electric current. Acting in this manner, electrization has been known to reunite an old fracture. (See Electro-Surgery.)

The great and peculiar sensitiveness of the skin to electricity is explained in part by the fact that the epidermis as a whole is so poor a conductor, and the electricity enters it by points through the sudoriferous and sebaceous glands, and the smaller the diameter of the point at which the electricity enters a body the greater the density, the strength of the current being constant. When now an electrode is applied to the body, the entire current, instead of diffusing itself over the whole surface, enters at the glands, where there is best conduction, and consequently excites pain. For the same reason, to a greater degree, electricity applied by means of a metallic brush is far more painful than when applied with a broad metal or sponge.

For the same reason a wet sponge electrode, when lightly touched to the surface of the body, causes more pain than when firmly pressed on the skin.

One effect of faradizing the skin is the phenomenon of "goose-flesh," popularly so called. This is noticed not only where the electrodes are applied, and between them, but at a distance. It is more observed in the nervous and feeble than in the hardy and strong. It may be excited by weak currents of momentary duration. In some persons it cannot be excited at all.

Action of the Galvanic Current.—The effects of the galvanic current on the skin differ somewhat from those of the faradic. At both poles there is a burning sensation, which increases in intensity with the strength of the current and the length of the application. The sensation, when the current is closed, is like that of a mustard plaster, or, with a very strong current, that of a hot iron pressed on the skin. The "goose-skin" sometimes appears as under the faradic current, but it lasts longer. It appears only around the poles, and not beneath them, at the points of contact. At the positive pole, in some cases, there appears under the electrode, at first, a shallow depression, and the skin is pale, but soon hyperæmia appears, and many little elevations here and there. When a strong current is used an ischæmic appearance is presented beneath the electrode, and a red areola extends for some distance around.

At the negative pole substantially the same phenomena appear, but the hyperæmia arises more rapidly, and is more intense and extended.

The general sensation caused by the galvanic current is then, in character, substantially the same at both poles. In degree of action there is a certain difference, since the change at the negative develops more rapidly and powerfully.

The above phenomena we have repeatedly demonstrated on a variety of temperaments. We have observed that the rapidity and strength of the action are considerably modified by the individual and the resistance offered. Soft, thin, and delicate skins appreciate the burning feeling and the various stages of hyperæmia more quickly than skins which are coarse, thick, and hard.

Ziemssen, who has carefully studied this subject, states that unpolarized electrodes are necessary in order to obtain the complete results with certainty.

Chemic Effects of the Galvanic Current on the Skin.—The chemic effects of the galvanic current on the skin differ not only in degree but in kind. Under the negative pole—when metallic electrodes of moderate diameter are applied on the skin, slightly moistened—there appear small, pale vesicles, that are transparent and are not raised much above the skin. This phenomenon is produced by a current that causes a strong burning sensation. These vesicles contain fluid and layers of epidermis. The fluid is alkaline. When the strength of the current is increased the fluid becomes of a brownish color, and blisters are formed and a red areola appears. The serum that comes out on the skin is alkaline. These blisters, and all the other phenomena, as has been often demonstrated, appear more rapidly on delicate than on thick skins, and when fully formed they are a long time in healing, and for days and weeks a yellowish and brownish discoloration may be observed at the points where the skin was acted on.

If the application be still more protracted little ulcers are formed, that are also slow to heal perfectly, but are not painful, and cause no annoyance.

At the positive pole, when a strong current is used for some time, a blister appears, accompanying the other symptoms of "goose-flesh," ischæmia. The blister is colored in its centre a yellowish brown. The serous fluid that comes from the blisters is acid. The metallic electrode becomes black through oxidation. In order to demonstrate this action of the positive pole, it is better to have the connection at the negative pole established by means of a broad, soft, and well-moistened sponge.

Ziemssen states that by this experiment, made with thermometers, no elevation of temperature takes place either at the positive or negative pole.

In all these chemic actions of the galvanic current on the body, it is probable that more or less ozone is produced, and it is not impossible that the ozone thus produced may in some way modify the effects.

Electro-anæsthesia.—It has for some time been a matter of dispute whether a slight anæsthesia can be produced by the electric current. It is well known that for a number of years some dentists have been accustomed to connect the forceps for extracting teeth with one pole of an electro-magnetic apparatus while the patient rested his foot on the other pole, so that as soon as the forceps seized hold of the tooth a current is established. Although this method of producing anæsthesia is not now received with favor, there is no question that the electric currents do have a slight benumbing effect. That the pain caused by the prick of a pin, for example, is less sensitively felt when a strong faradic current is passing through the part where the puncture is made, we have practically demonstrated on the hand and other parts of the body.

Knorr, of Munich, has availed himself of the anæsthetic effects of electrization for opening felons and buboes.

We have also experimented on inflamed and irritated mucous membranes. In rhinitis, pharyngitis, and laryngitis, we have for years been accustomed continually to make use of the benumbing effects of electrization.

It has a very slight anæsthetic effect on irritated and inflamed mucous membrane, and those on whom it has been employed desire to have the applications repeated.

Induced current vibrations of extreme rapidity have been found to possess anæsthetic properties, although it is necessary that these vibrations shall be a certain number per second.*

Electrical Excitability of the Skin.—Tschiriew † and De Watteville have pointed out a method by which the absolute and relative excitability of the cutaneous nerves can be readily tested. The principles of their method are: 1st. Elimination of all the sources of variation in the strength of the currents due to the variable thickness of the epidermis, and the different positions of the electrodes, etc., by intercalating in the circuit such resistances as to make such variations insignificant. 2d. Elimination of the variable abundance of nervous elements in the skin, by exciting it at a constant number of points, dispersed over a constant surface.

* "A Study of Electro-Anæsthesia," by W. F. Hutchinson, 1893.

† Brain, Part vi.

CHAPTER IV.

ACTION OF ELECTRICITY ON THE BRAIN AND SPINAL CORD.

Direct Application.—It has been shown by Fritsch and Hitzig that in the cerebral convolutions there are centres for the production of voluntary muscular movements in various parts of the body. These physiologists took off the upper part of the skull of a dog, and by means of weak galvanic currents excited the exposed brain, locating the current, as far as possible, in small portions. They found that when certain definite portions of the anterior convolutions were excited, movements were caused in certain groups of muscles on the opposite side of the body. Continuing their researches, they showed that there are definite nerve-centres for the nerves that preside over the muscles of the neck, the foot, and the face, for the extensor and adductor muscles of the forearm, and for the flexor and rotator muscles of the arm.

Professor Ferrier, of King's College, London, has made similar researches with the faradic current, and with it has investigated the brains of fish, frogs, dogs, cats, rabbits, guinea-pigs, and monkeys. He has studied not only the cerebrum, but the cerebellum, the corpora quadrigemina, and other portions of the brain. Electrization of the optic thalami produced no result. Electrization of the corpora striata caused the limbs to be flexed. Electrization of the anterior tubercles of the corpora quadrigemina caused dilatation of the pupils and opisthotonos; while electrization of the posterior tubercles caused the animal to make all sorts of noises. Electrization of the cerebellum caused movements of the eyeballs. We have carefully studied this subject on the brains of dogs, rabbits, cats, and pigeons. We used both currents, of varying degrees of strength, and studied also the question of diffusion of currents. Our provisional conclusions were, that the surface of the brain was electrically excitable; that the theory advanced by Dupuy and other French observers, that the excitation was due to the diffusion of the currents to the central ganglia, was not tenable.* Dr. Bartholow † had made similar experiments on the brain of a living woman, exposed by cancerous disease.

Effects of External Galvanization of the Brain.—The leading effect of medium and strong galvanization of the brain by external application in the living human subject is different. When one electrode is placed on the forehead and the other on the occiput, or one on the summit of the

* Archives of Electrology and Neurology, May, 1874.

† *Ibid.*

head and the other on the stomach, galvanization is followed by little if any tendency to vertigo. When a current of even feeble tension is passed from temple to temple, or from one mastoid bone to its fellow, very decided dizziness is at once perceived, which continues during the operation of the current, and becomes most decidedly manifested at the moment the circuit is broken.

During the passage of the current there is a very marked and quite irresistible tendency to lean toward the positive pole, while objects in view seem to move in the same direction. When the circuit is opened there is a reversal in the direction of the seeming movements, and the experimenter instantly bends in the opposite direction toward the negative pole.

For these phenomena an ingenious and plausible explanation is given by Hitzig. When the current passes from the forehead to the occiput, the right and left lobes of the brain and all that pertains to them are equally or symmetrically influenced, and little if any dizziness is perceived. Place, however, the anode upon one temple and the kathode upon the other, and mark the readiness with which dizziness is produced.

In this operation the brain is no longer symmetrically affected. One hemisphere is in a condition of anelectrotonos, or diminished irritability, while the other is in a condition of catelectrotonos, or increased irritability, or, as it is expressed, there is a falsification of the muscular sense, a disturbance of the equilibrium, and the apparently involuntary inclination toward the anode is in reality a voluntary effort to restore the imaginary loss of balance.

Hitzig indicates several degrees of galvanic giddiness.

1. A mere sense of fulness in the head. This feeling is caused by a mild current when broken, but not usually when the current is running, nor so markedly when the current is closed. Certain temperaments, however, experience this feeling not only when the current is broken, but also when it is running.

2. Apparent movements. These are produced by stronger currents. Objects when the current is running appear to go from the positive to the negative pole; when the current is broken the apparent movement is reversed.

3. Staggering. This is produced by stronger currents. In impressible temperaments very mild currents may produce it.

Movements of the Eyes.—Movements of the eyeballs have also been observed by Hitzig during the second and third stages of dizziness. When a strong current goes transversely through the head, and its direction is changed, movements of the eye, resembling nystagmus, appear. There is a jerk, and then a further movement. If the positive pole be in the right mastoid, and the negative in the left, both eyes are jerked toward the left, and kept there, provided the current be sufficiently strong.

Notwithstanding these strong evidences of the possibility of directly influencing the brain by external applications of the galvanic current, Dr. H. A. Hare * details some experiments on dogs which seem to him to prove that no such influence is possible, and that any therapeutic benefit that comes from applications to the head comes through reflex action and is not due to the direct action of the current on the cranial contents. Deve,† on the contrary, reports some interesting experiments which seem sufficient to prove that electricity acts perfectly within the central portions of the brain. These experiments will be referred to in more detail further on.

SPINAL CORD.

Rigid cramps of all the muscles of the trunk and extremities follow electrization of the spinal cord when an electrode is placed at either extremity of the cord. Cramps of the same character are also produced when one electrode is applied to the anterior and the other to the posterior column, either at their upper or lower extremities.

If the spinal cord be divided at about its centre and the lower half electrized, only the muscles of the lower or hinder limbs will contract. If the upper half be electrized, only the muscles of the fore limbs will enter into contraction. The results will be the same, whether the cut extremities are separated or brought in close contact, in which latter condition no impediment is offered to the passage of the current. The above researches of Weber have been confirmed by our experiments on dogs and rabbits. The effects are produced by both currents.

Inhibitory Effects.—At the moment of closing and breaking a galvanic current its action upon the cord is manifest by the contraction of the muscles of the body and limbs; but during the passage of the current no contractions are observed, and a paralyzing effect soon takes place. The cord remains insensible to any stimulus that may be applied to it as long as the current is passing, but at its cessation any mechanical irritation will give rise to the usual tetanic convulsions. This diminution of excitability is confined alone to the spinal cord, for if the motor nerves and muscles are traversed by an induced current (while the cord is under the influence of the galvanic) they contract vigorously. The galvanic current applied through the spinal cord for a long time produces paralysis.

According to Mayer, if a mild faradic current be applied to the cervical regions of frogs that are in an irritable condition, movements of the lower extremities occur. Electrization of the posterior columns produces these movements easier than electrization of the anterior columns. If the posterior columns are removed no movements occur. If the cord is divided into halves, posteriorly and anteriorly from above nearly down to

* Therapeutic Gazette, December 15, 1893.

† "Dans l'électrization galvanique de la tête, le courant passe-t-il à la surface du cerveau ou dans sa profondeur?" Union méd. du Nord-est, Rheims, 1893, xvii., 37-39.

the origin of the sciatic nerve, electrization of the posterior half produces movements, but electrization of the anterior does not. If the posterior roots on the trunk of the brachial nerve are electrized the movements are produced just as when the cord itself is electrized. Fick, however, declares that the anterior columns respond to faradization.

Cilio-spinal Centre.—The cervical sympathetic nerve, which animates the radial fibres of the iris, takes its rise from the spinal cord between the seventh cervical and the sixth dorsal vertebræ.

If this portion of the cord be galvanized, the excitation is transmitted to the cervical sympathetic nerve, and thence to the iris, producing dilatation of the pupil. This point has been termed by Budge and Waller the centrum cilio-spinale. A ganglion near the fifth lumbar vertebra which, on being electrized in animals, produces contractions of the rectum and bladder, is called the ganglion genito-spinale.

The first of these points, the centrum cilio-spinale, can be demonstrated by external applications both of the galvanic and faradic currents, and is of great importance in general faradization. The ganglion genito-spinale also is probably directly, though not so demonstrably, affected by external electrization of the spine.

CHAPTER V.

ACTION OF ELECTRICITY ON THE SYMPATHETIC AND PNEUMOGASTRIC.

The influence exerted by electricity upon the sympathetic system of nerves is a subject of exceeding interest. There can be no question in regard to the phenomena that attend the direct applications of either current in physiologic investigations, and it is not surprising that those who first witnessed these phenomena regarded them as significant of the possibilities of this agent in the treatment of diseased states of the central nervous system. Unfortunately, external or percutaneous applications of electricity—galvanic or faradic—failed in great measure at that time to substantiate the hopes entertained, and the therapeutic results in those cases where the sympathetic was supposed to be involved were altogether unsatisfactory. We do not have to seek far for the causes of this failure. They are to be found in an incorrect appreciation of the relation of electricity to the human body, based upon an imperfect knowledge of the physics of electricity, and the lack of suitable appliances and instruments of precision.

In view of the wide field opened to us, in case it can be demonstrated that in therapeutic doses electricity can be made to affect appreciably the deeper nerve structures, it seems to us most desirable to gather together some of the facts bearing upon this interesting question. This seems to be the more necessary because there are many who honestly doubt the possibility of electrically stimulating any part of the central nervous system by ordinary percutaneous methods of application. Certainly no one who has witnessed an execution by electricity can doubt its power to directly influence the most distant organs; and if fifteen hundred volts will instantly paralyze every bodily function, would it not be strange if fifty volts, or one-fiftieth of the power necessary to kill, possessed no influence on the brain and the deeper-seated nerve-structures? Reasoning from analogy, the facts are all in favor of this probability, for in the administration of drugs far less than one-fiftieth of the dose necessary to destroy life is often productive of appreciable therapeutic effects.

We possess very few pathologic facts in support of the sympathetic origin of disease, and therefore, in studying this question, and the one that we are about briefly to consider, viz., the action of electricity on the sympathetic, it will be instructive to refer, 1, to the effects of electrization on the exposed sympathetic, and to a few of the ascertained facts in regard to the influence of the sympathetic on the functional activity of various organs; 2, to ascertain phenomena observed after percutaneous applications in the neighborhood of the sympathetic; 3, to clinical observations illustrating the effects of applications of electricity to the neck in certain conditions supposed to be dependent upon disorders of the sympathetic.

Beginning with the original experiments of Claude Bernard as far back as 1832, we find that division of the sympathetic causes a multitude of phenomena. The cornea flattens, the pupil contracts, the globe of the eye retracts, the palpebral fissure decreases in size, the conjunctiva reddens, and there is a very positive elevation of temperature due to a general dilatation of the vessels of the head and neck on the side operated upon. Electric stimulation of the cephalic extremity of the severed nerve, on the contrary, causes the vessels to contract, and all the various phenomena to disappear for the time being.

The influence of the vaso-motor nerves of the eye was made evident a century ago by the investigations of Pourfour du Petit. The vessels of the iris dilate on division of the sympathetic, followed by immediate contraction when the peripheral extremity of the nerve is submitted to electric excitation.

Brown-Séquard, experimenting upon guinea-pigs and rabbits, by dividing the cervical sympathetic, found after the lapse of a few months an appreciable atrophy of the brain of the same side.

That the intercranial blood pressure is in some degree regulated by the cervical sympathetic, seems altogether probable on account of the anatomical relationship. The nerves of the pia mater, and those associated with the vessels of the cortical substance, are traced back to the sympathetic plexus, irritation of which causes immediate contraction of the cranial vessels. Perhaps the most conclusive experiments in this direction were made by Fisher.* With the aid of a hæmato-dynamometer, he was enabled to show that faradization of the exposed sympathetic of a horse resulted in a constant increase of arterial pressure, as well as increased tension of the arterial walls.

Intestinal peristalsis is undoubtedly more or less under the influence of the sympathetic; the movements of the intestines in animals being arrested on irritation of the splanchnic nerve, while the thoracic and abdominal sympathetic impart accelerating influences to these movements. The uro-genital apparatus also, including the bladder, the ureters, seminal vesicles, and the uterus, respond to experimental irritation of the sympathetic plexus of the abdominal cavity.

The secretory processes of the body depend largely upon the influence of the vaso-motor branches of the sympathetic, the secretion of the gastric

* Deutsches Archiv für klinische Medicin, 1875.

juice being carried on automatically by the ganglia situated in the walls of the stomach. The nutrition of the mucous membrane must in a measure be dependent upon this system of nerves, since extirpation of the solar plexus is followed by hyperæmia, extravasation of blood, and ulceration. Stimulation and extirpation of the abdominal sympathetic plexuses affect the intestinal secretion, the evacuation, and the general nutrition of the intestines. The vaso-motor nerves of the liver are derived from the sympathetic. These nerves have their origin near the floor of the fourth ventricle of the brain, entering the sympathetic, and thence with the blood-vessels pass to the gland itself. Puncture of these vaso-motor nerves produces paralytic dilatation of the vessels and the production of sugar—the same results that follow puncture of the floor of the fourth ventricle itself. These effects were supposed to be produced by stimulation, but the experiments of Cyon and Aladoff, in 1871, made it quite evident that the appearance of sugar in the urine came not from stimulation, but from paralysis, of the sympathetic. Not only did they find that removal of the cervical ganglia of the sympathetic was invariably followed by diabetic symptoms, but also when the nerve-branches, central and peripheral, with which it is connected, are divided. Interference with the function of the sympathetic affects the excretion from the kidneys in more ways than the elimination of sugar. Albuminuria, hæmaturia, with quantitative and qualitative changes in the urine, together with disturbances in the nutrition of the kidney and suprarenal capsules, have often been observed. The spleen and the entire genital apparatus also have intimate connection with the sympathetic through their nerve-supply, irritation of which produces marked circulatory disturbance in both the spleen and penis.

Burckhardt * and Ziemssen's † experiments upon the dead body indicate the possibility of directly affecting the cervical sympathetic through percutaneous application of the galvanic current. They thrust partially insulated needles into the sympathetic from behind, connecting their free ends with a sensitive galvanometer. Electrodes connected with a galvanic battery were placed, one near the angle of the lower jaw, and the other at the manubrium sterni, and when the circuit was closed the movements of the needle indicated the action of an electric current on the nerve itself.

Again, if one electrode, the anode, is placed at the manubrium sterni, or in the neighborhood of the cilio-spinal centre, and the kathode at the inner border of the sterno-cleido muscle, a little below the auriculo-maxillary fossa, and a current of sufficient strength employed, the pupil of the same side may be made instantly to dilate on closing the circuit, followed by a gradual contraction. The difficulty of demonstrating this phenomenon in most persons is due to their susceptibility to the action of the current, many suffering from extreme vertigo, and even nausea and faintness,

* Deutsches Archiv für klinische Medicin, 1878.

† "Die Electricitat in der Medicin."

before the current is sufficiently strong to produce contractions visible to the unaided eye. By the aid of the pupillascope, however, it has been found possible to detect these changes in the eye with even exceedingly weak currents. Changes in the pupil so slight as to escape direct observation are yet associated on the retina with what are called dispersion circles, the character of which accords with the degree of contraction or dilatation of the iris. While it seems to be entirely probable that the dilatation and subsequent contraction of the pupil, on closing the circuit, are due to the action of the current on the sympathetic pupillary branches, nevertheless it is impossible not to take into consideration the fact that reflex influences are potent factors frequently in the movements of distant parts, and therefore in these experiments there is some ground for the claim that pupillary changes may be reflex in character.

The circulation is unmistakably influenced by strong and prolonged applications of electricity to the neck and neighboring parts, and the reason why the test fails experimentally in so many cases is because of the inability of the ordinary subject to endure the necessary strength of current.

In the many tests that we have made to determine whether or not it is possible to get any appreciable electric effect upon the sympathetic by percutaneous applications, we have occasionally met with interesting and suggestive results. Every one who has much to do with the medical application of electricity is aware how varied is the susceptibility to its effects. The two following records are interesting illustrations of this fact, and of the probability of direct electric stimulation of the sympathetic by eternal applications.

Personal Observation.—Male, aged 31, with a normal pulse of 75. An electrode of plastic sculptor's clay, 3 cm. in diameter, and connected with the positive pole of a galvanic battery, was applied to the hollow just above the clavicle, at its juncture with the sternum. The current was gradually increased to 75 milliamperes, which caused a decrease in the frequency of the pulse of ten beats in less than one minute, and this decrease in the rapidity of the heart's action continued so long as the electrodes remained in position. On removing them the pulse would almost immediately increase to its normal frequency, and also the respiration, which was invariably affected equally with the pulse. The results in this case clearly depended for the most part on stimulation of the inhibitory fibres of the pneumogastric, and the fall in the heart-beats may have borne no relation whatever to the sympathetic system. None the less, however, was the test of value in demonstrating the possibility of influencing the deeper-seated nerve-structures by currents of sufficient strength. Only occasionally can a person be found who can endure such a strength of current through small electrodes, and placed as indicated; but few opportunities, therefore, have been afforded of getting so striking a result. We have observed the good effects of electricity in chloroform poisoning, but not through the use of the galvanic current, the tendency of which is undoubtedly to inhibit the action of the heart. The induced current, as ordinarily applied, certainly does not affect the inhibitory fibres controlling the action of the heart, and its undoubted influence over respiration must be ascribed to the action of the current on the accelerating fibres of the vagus and sympathetic that refer to the respiration. The induced current of electricity, therefore, does good in chloroform narcosis in increasing respiratory activity, the strength of current necessary for this purpose being insufficient to materially interfere with the movements of the heart through its action on the inhibitory fibres of the vagus that control it.

The next record, as compared with the first, illustrates how varied are the susceptibilities of different individuals to the effects of electricity.

Personal Observation.—Female, aged 23, with a normal pulse of 72. Electrodes of the same size and applied as in the previous case; and yet 15 to 20 milliamperes, was all this patient could possibly bear without a tendency to faintness and nausea. Confining the strength of the current to a point below the production of these symptoms, it was most interesting to note its very positive effects upon the pulse. This effect was not immediate, as in the former case, when currents of far greater strength were used; but by keeping the electrodes in position for several minutes, it was found that the pulse would invariably sink to 65. We had under observation a young man aged 22, with a remarkably torpid circulation. His pulse seldom arose above 48, and under the influence of a strong current it could at will be reduced to 43. If these effects upon the pulse are due, as is probably the case, to a stimulation of the inhibitory function of the pneumogastric, it is only an additional argument in favor of electrically influencing the sympathetic; for if the vagus is influenced by percutaneous applications, the sympathetic ought also to be affected as the threads of current pass from pole to pole.

Action of Electricity on the Cephalic, Thoracic, and Abdominal Ganglia.—Section of the sympathetic causes, as we have seen, increase of heat in the ear.

Now if the cephalic end of the divided sympathetic is electrified, the increased temperature of the part is lowered; but if the electric current be passed through the large diameter of the ear, the temperature is further increased. On the other hand, if there has been no division of the sympathetic, and the ear is electrified, the heat in that part is lessened.

Valentin found that the galvanization of the superior thoracic ganglia revived the pulsation of the heart after it had ceased, and increased the frequency of the beats when already in action. Mild galvanization of the splanchnic nerves that arise from the six lower dorsal ganglia of the sympathetic increases, while strong galvanization diminishes, the peristaltic action. The investigations of O. Tschetschott * and Przewaski † are interesting in this connection.

* Abstract in St. Petersb. med. Wochenschrift, No. 32.

† Deutsche med. Wochenschrift, No. 43.

Effect of Direct Electrization of the Pneumogastric and on the Respiration.—MM. Arloing and Tripier have shown that section of the pneumogastric below the medulla oblongata so far modifies its irritability that the action of the heart is not arrested, or but for a short time, by the faradization of the distal end of the cut pneumogastric.

The same authors believe that weak faradic currents cause a slight increase in the rapidity of the beats of the heart and elevation of the blood-pressure in the arteries.

They found that the right pneumogastric has a more powerful influence over the heart than the left. Faradization of the peripheral end of the divided pneumogastric causes arrest of the action of the heart, sudden irregularities of its rhythm, and some diminution of pressure. Faradization of the central end causes retarded and diminished pressure.

According to MM. Arloing and Tripier, faradization of the intact pneumogastric with feeble currents does not accelerate respiration; faradization with medium currents causes sudden inspiration and forced expiration; faradization with strong and powerful currents causes reflex coughing and vomiting. The same observers found that the left pneumogastric has a more powerful influence over respiration than the right.

The discovery that the right pneumogastric has a greater power over the heart than the left was made by Masoin, of Belgium, about the same time as it was made by Arloing and Tripier. Masoin found the movements of the heart were stopped by the galvanization of the left pneumogastric. It was possible to restore the movements by a mechanical excitation, such as striking the heart with the finger; but after the movements were stopped by galvanization of the right pneumogastric, it was not possible to restore them in that way.

Dr. Brown-Séquard * states that he has found the same differences to exist in men as in animals, judging from experiments made not by electricity, but by pressing on the nerves near the angle of the jaw.

Arrest of Respiration by Galvanization of the Laryngeal and Other Branches of the Pneumogastric.—It has been shown by Brown-Séquard † that electrization of the upper or the lower laryngeal nerves causes arrest of the respiration, and Bidder has shown that a reflex spasm of the glottis may be caused in the same way. Electrization of the œsophagus and pharynx may sometimes produce the same effect. If the upper laryngeal nerve is electrized after the chest is opened, the arrest of the respiration does not take place as easily as when the chest is not open. The respiration, when thus arrested, usually returns in the course of a quarter or half a minute, whether the electrization is continued or not.

The effect of electrizing the pneumogastric on the respiration is modified by two factors—the portion of the nerve that is electrized and the

* Archives of Scientific and Practical Medicine, January, 1873, p. 92.

† Loc. cit., p. 96.

strength of the current. Mild galvanization of the pneumogastric in the lower part of the neck may increase the respiratory movements; weak electrization in the upper part of the neck, near the origin of the nerve, may arrest respiration.

A mild current may increase the respiration or diminish it, or it may have no effect whatever.

A medium current may arrest respiration and cause spasm of the glottis and of the muscles of inspiration.

A powerful current may paralyze the diaphragm, and may produce death without the accompanying symptoms of agony.*

Coughing.—A prominent effect of electrizing the pneumogastric is coughing. This symptom may be excited by external as well as by internal applications, and by the faradic as well as by the galvanic current.

This phenomenon we daily observed in the operation of general faradization. The same effect follows the use of strong interrupted galvanic currents.

According to Donders, the pneumogastric, when acted upon by the galvanic current, conforms to Pflüger's law of contraction; in the region of anelectrotonos its irritability is lessened; in the region of catelectrotonos its irritability is sometimes increased.

Action of External Applications of Electricity on the Pneumogastric and Cervical Sympathetic of Living Uninjured Men.—The experiments above recorded were made chiefly on the exposed nerves of animals, and the applications were made directly to the nerves by one or both poles. Keeping in mind the considerations previously adduced, we proceed to examine into the effect of external applications of electricity on the cervical sympathetic and the pneumogastric of living men in health.

In our attempts to solve the problem, we have experimented on a large variety of individuals of different ages and by different methods of application. One of the electrodes is placed in the mastoid fossa, and the other over the seventh cervical vertebra, or at the top of the clavicle. Both directions of the current are used. We used in these experiments a current strength of from 5 to 15 milliamperes, from one to five or ten minutes.

The general results of our researches may be thus summed up:

1. A slight feeling of drowsiness. This sometimes began to be perceptible shortly after the electrodes were applied, increased up to a certain point, and continued for some little time after the *séance* was over. In many cases it is not observed until the lapse of five or ten minutes after the *séance.* The feeling, which was by no means constant, was usually so slight that it might not have been observed, had we not in our experi-

* Archives of Scientific and Practical Medicine, No. 1, 1873, p. 96. Whether these experiments were performed with the faradic or galvanic current is not distinctly stated.

ments kept closely on the watch for every sensation experienced during or just after the application.

Some individuals are amazingly susceptible to this soporific effect of galvanization of the neck. A young lady whom we were treating for facial acne by central galvanization, was frequently put right to sleep within one minute after the application began. Her eyes would close and her head would droop and nod; and when the electrodes were removed she would awake but slowly, and with a vacant look and drowsy feeling, such as we all experience when we are suddenly roused from a nap. This effect followed any sort of application around the neck with either pole and in any direction.

On the accepted theory that a state of cerebral anæmia predisposes to sleep, we should reason, *a priori*, that electrization of the sympathetic ought to induce a feeling of drowsiness, since on some individuals it unquestionably diminishes the current of blood in the brain, and experimentally we have found that it does thus induce a slight and temporary disposition to sleep although; this result is probably far less marked than it would be if, without injury to the living subject, the application could be made directly to the ganglia, and this effect is by no means uniform, but varies with the strength of the currents and with the temperament of the individual.

2. A feeling of warmth through the system with sensible perspiration. This was not a constant symptom, although it was oftentimes very decided. To produce sensible perspiration usually requires a strong current and a long application. The extent to which this was felt was manifestly dependent on the strength of the current and the length of the application. It was usually felt but a short time after the *séance* was completed. We have observed this effect more frequently and more markedly in the susceptible and nervous than in the cold and phlegmatic, and most frequently in more or less pathologic cases.

3. A marked effect on the pulse. The pulse was sometimes accelerated, but more frequently lowered, two, three, four, or more beats.

In order to determine the effects of electrization of the sympathetic on the pulse, we made the examinations immediately before and immediately after the applications. Every precaution was taken to avoid error, by allowing an interval of rest before the sitting, in order to give time for the subsidence of the pulse to its natural condition from any excitement that it may have received from the exertion of walking or the labor of partially disrobing. In cases of doubt the whole minute was counted, in some instances several times in succession. A patient unaccustomed to the sensation produced by the electric current, or to the *modus operandi* of its employment, might experience an acceleration of the pulse from simple mental excitement, not only prior to or at the commencement of the sitting, but also during or after the application. Error from this cause was in our cases manifestly impossible, and all the others on whom we experimented with a view to obtain physiologic results were so well familiarized to the medical employment of electricity that they would receive any treatment proposed with cool indifference. In order still further to guard against error, and at the same time to observe the continuance or permanency of the effect of the experiments, we repeated, in some instances, our examinations of the pulse at intervals of fifteen minutes or half an hour after the sitting was over.

A corroborative evidence that these changes in the pulse were due to the action of the current, and not to mental excitement, is found in the fact that, after an interval of five, ten, or fifteen minutes, the pulse returned to its original condition.

These changes in the time of the pulse were also accompanied by perceptible changes in its character, which, if careful sphygmographic observations had been made, might perhaps have been reduced to some general law.

Eulenburg and Schmidt found that when the positive pole of from twenty to forty of Daniell's elements was placed at the manubrium sterni, and the negative pole in the auriculo-maxillary fossa, the pupil of that side was at first slightly dilated and afterward contracted. These changes in the pupil are by no means uniform in their appearance. In some cases they appear at once after closing the circuit, and in others after the lapse of half a minute or minute, and in others after interruptions. These phenomena are liable to many variations, according to the strength, length, and locality of the applications. If an electrode is placed in the auriculo-maxillary fossa of each side, the changes in the pupil occur on both sides, but are more marked on the side on which is the negative pole. The same application, continued for some time with a strong current, reduced the normal pulse from 4 to 16 beats a minute and the pathologic pulse even more, diminished the tension in the carotid and vertebral arteries, and markedly altered their sphymographic tracings. The same observers found that galvanization of the spine also diminished the beats of the pulse.

Effect of External Electrization through the Neck on the Retinal Circulation.—In order to determine the effect of external applications of electricity through the neck on the retinal circulation, we have made many experiments with the aid of a number of leading ophthalmologists.

These experiments, which have been frequently repeated with different individuals, with different strengths of current, and with different batteries, seem to us to demonstrate the following propositions:

1. Galvanizing or faradizing the region of the cervical sympathetic has a marked temporary influence over the retinal circulation. It may cause contraction of the arteries or dilatation of the veins.

2. The faradic current produces precisely the same effects on the reti-

nal circulation as the galvanic, only more slowly. The physiologic difference between the currents in this respect is therefore a difference of degree and not of kind.

3. Mild currents and short applications caused contraction of the blood-vessels of the retina, while strong currents and long applications caused dilatation. Much seemed to depend on the temperament and condition of the individual. What would cause contraction in one would in the other cause dilatation.* These varying effects correspond with clinical experience.

4. When the patient on whom the experiment is made is in an excited or irritable condition from any cause, or from previous electrization, even a mild current will sometimes cause dilatation at once, without any early contraction.

5. The contraction which takes place is sometimes followed, a few minutes after the close of the *séance*, by dilatation which is greater than normal.

6. The dilatation which takes place is sometimes followed by contraction after the close of the *séance*.

In some of the experiments no effect on the retina could be detected. Impressible and nervous temperaments seem to exhibit changes in the vascular condition of the retina much more readily than cold and phlegmatic temperaments.

The question now arises, Whether these changes in the retinal circulation were due to the effect of the current on the sympathetic or on the pneumogastric, or did they take place through the spinal cord or by reflex action?

This question is answered by comparing the results of these experiments with the result of experiments made by Duchenne and Professor Léigeois, of Paris. These gentlemen laid bare the cervical sympathetic in a rabbit, and electrized it with both currents in the same manner that we electrized the necks of the individuals on whom we experimented. The results on the circulation in the rabbit's ear were in every distinctive feature identical with the results on the retina when the galvanic current was passed through the neck of the living human subject.

The other effects of galvanizing the region of the cervical sympathetic —disposition to sleep, sweating, increased circulation in the extremities, etc.—seem to confirm these physiologic observations.

These experiments have been partially confirmed by Onimus, who has shown that the circulation of the retina may be influenced by galvanization of the cervical sympathetic. He observed hyperæmia, but this, as we have shown, is not a constant effect.

* The opposite and contradictory results obtained by different observers who have studied the effects of chloral, bromide of potassium, etc., on the retinal circulation, may be similarly explained.

Experiments with the Sphygmograph.—For assistance in the study of sphygmography we are under obligations to Dr. Roger S. Tracy. A few samples of the observations are represented in the cuts.

FIG. 40.—Normal pulse.

FIG. 41.—After five minutes' galvanization of the sympathetic.

FIG. 42.—After ten minutes' galvanization of the sympathetic.

FIG. 43.—Five minutes after the close of the séance of galvanization of the sympathetic.

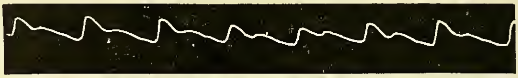

FIG. 44.—After five minutes' faradization of sympathetic.

FIG. 45.—After nine minutes' faradization of sympathetic.

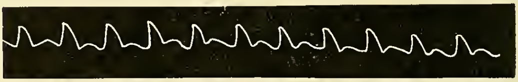

FIG. 46.—After twenty minutes' faradization of sympathetic.

FIG. 47.—After fifteen minutes' general faradization.

FIG. 48.—Five minutes after close of séance of general faradization.

From these experiments we derive the following conclusions:

1. Both currents—faradic and galvanic—when applied in such a way as to traverse the region of the neck in which the pneumogastric and cervical ganglia of the sympathetic are situated, markedly affect the pulse.

2. The effect is chiefly shown in abruptness of the systole, and in abruptness of the diastole, and in shortening of the interval between the cardiac impulse and the arterial impulse. In general it may be said that the force of the pulse is increased. Its rapidity may be either increased or diminished, according to the length of the application and the strength of the current, and analogy would lead us to believe that the effect must widely vary with the individual. The arterial impulse increased probably from the effect on the vaso-motor nerves.

3. The effect of general faradization was to prolong the systole and the interval between the cardiac and the arterial impulse. The abruptness, and the systole that is so marked during and after faradization through the neck, was not observed after general faradization. A calming, soporific influence is very frequently produced by general faradization, and the effect on the pulse harmonizes with this observation.

4. These effects on the pulse gradually pass away, but are distinctly traceable for a number of minutes after the electrodes are removed.

The effect of the current thus applied on the circulation is probably a complex resultant of the effect of the electricity on the pneumogastric, the sympathetic, the depressor, and the spinal cord. To differentiate these effects is manifestly impossible.

CHAPTER VI.

ACTION OF ELECTRICITY ON THE NERVES OF SPECIAL SENSE.

Action of the Galvanic Current on the Optic Nerve.—The galvanic current, when applied to the eye, causes both flashes of light and perception of color.

If one electrode is placed on the tongue, or on any part of the mucous surface of the mouth or nose, and the other on any part of the surface of the body, the flash is readily perceived.

The character of these flashes is variously modified by the strength of the current and the suddenness of the interruption. The temperament of the patient also modifies the reaction, and the effect of the two poles is usually quite different.

We have studied this subject with various strengths of current, and on subjects of both sexes differing widely in age and temperament.

In one subject—a young man of nervous temperament—the positive pole placed over the eye, with a weak current, caused a white central spot, with a light areola. The white central spot varied in shape between that of a quarter or half to a full moon. When the negative pole was placed over the eye, the central spot appeared of a bluish or purplish color, and the areola was the same as under the positive pole. In both cases the areola seemed to consist of waves of light radiating from the centre toward the periphery.

In making these experiments, the pole that is placed over the eye is armed with a soft sponge, and is pressed firmly on the closed lid, while the other is applied at the back of the neck, or is held in the hand of the subject.

In another subject, a young physician of good health, and nervo-sanguine temperament, the positive pole from a current of six cells caused a central disk of a pink color, and from this spot violet waves radiated through the areola. The pink disk appeared when the current was closed, the violet areola flashed out when the current was broken. The negative pole produced reactions every way similar. This subject could not bear very strong currents.

Several other physicians on whom we experimented could not distinguish any central disk, but all could readily see the light areola.

The conclusions from the above, and numerous similar experiments made in different individuals, are as follows:

1. A mild as well as a strong galvanic current applied to the eye, and interrupted, causes a flash or glimmer of light to appear.

2. A medium or strong galvanic current causes, in addition to the flash of light, a distinct central spot of varying shape, and both the central spot and the areola may be of various colors, as pink, purple, yellowish, and violet.

3. With some individuals, though not with all, the colors of the central spot and of the areola, and their relative arrangement, appear differently under the two poles, and also differently at the closing and opening of the circuit.

4. All those reactions, like all other electro-physiologic reactions, are variously modified by the temperament of the individual operated on and by the strength of the current.

The above conclusions, as will be seen, differ somewhat from those of Helmholtz and others who have studied this subject. The differential action of the ascending and descending currents we have not been able to demonstrate, and see no way of demonstrating. We believe that here, as in so many other electro-physiologic and electro-therapeutic procedures, the differential polar action has been confounded with the differential action of the ascending and descending currents.

Although the above reactions in their full degree can be most conveniently obtained by placing one electrode over the closed eye, and the other in the hand or at the back of the neck, yet the general reaction of the glimmering flash of light can be obtained by placing one electrode in the vicinity of the eye, or on any part of the face or beard, or in the mouth. In susceptible persons the flash comes from interrupted galvanization of the neck or spine.

Faradic Current.—The current from the primary or secondary coil of the ordinary faradic machines has little or no perceptible effect on the retina, as we have demonstrated by various experiments. We have found, however, by repeated observations, that the current from the long coils of the electro-magnetic machine manufactured by Kidder has a most decided action on the retina. The peculiar construction of the coil of this machine will be described in the chapter devoted to apparatus for electro-therapeutics. It is sufficient here to say that it is composed of three or four or more coils of insulated copper wire, the inward coil being short and thick, and the others gradually increasing in the length of the wires. These coils are not separate and distinct, as in ordinary machines, but connected, and are, so to speak, tapped at the points of union, so as to obtain a number of currents varying in quantity, tension, and physiologic power. It is from the fourth and fifth coils, which are not furnished to the majority of his smaller machines, that we obtain the reaction of the retina that we are now to describe. The reaction is best obtained by placing a medium-sized sponge electrode, well moistened, over the closed eye, or very near to the eye, while the other electrode is held in the hand or applied to some indifferent point, as the back of the neck, or arms, or feet. With a current of moderate strength thus applied, a circle filled with wavy, undulating light, or whitish spots or figures, appears. It is difficult to convey in language a precise description of this appearance. If snow-flakes could be elongated somewhat, and made to coil about in various directions, they would give a good idea of this reaction. If we look through a window at a thick, driving snow-storm, with large flakes, we can get a not very incorrect notion of the reaction, as we have over and over again demonstrated on ourselves and others. So far as we have been able to see, bright or variegated colors do not appear, except from the current of the fifth coil. The negative pole gives a stronger reaction than the positive; but not appreciably different in character. This reaction of the fourth coil of this machine is utterly unlike that which is obtained from either pole of the galvanic current. This effect has long been shown by the inventor of this machine, and has been illustrated by him. We were induced to question his assertions until we had first made experiments of our own with the different coils of the machine.

The Effect of Electric Irritation Compared with Mechanical Irritation of the Eye.—It is interesting to compare the reaction produced by the galvanic and faradic currents on the retina to the effects of mechanic irritation. We have found by experiment on ourselves that rubbing the eyes when closed, or partially closed, causes various and oftentimes beautiful appearances. Very frequently a central spot will appear, varying in shape and color, and changing in shape and color during the irritation. All conceivable shapes, and every grade of color, we have seen in this way over and over repeated; sometimes a mere circle of light shading off into darkness, and again a definite and well-formed object, brilliant in color, standing forth clear and beautiful against the dark background. Forms resembling a bouquet of flowers, or a cluster of stars, or various shapes of crystals, appear with such vividness that we love to prolong the experiment. Simple pressure on the side of the eyeball will cause reactions somewhat similar in kind (though less in degree) to those produced by the faradic current.

These reactions, however, are not very constant; they vary greatly with the individual, and with the same individual at different times. In order to obtain the most beautiful appearances, it is necessary to first look for a moment on bright light, or to have the eyes open in the full sunlight. It would seem that the retina must first become sensitive, by exposure to strong light, before the reactions can appear in their full extent.

Action of Electricity on the Auditory Nerve; Action of the Faradic Current.—The faradic current, when applied to the ear, or in the vicinity of the ear, causes a ringing, or humming, or rumbling sound, according to the method of application and the strength of the current. These sounds are due, in part, to the *susurri* of the muscles.

Action of the Galvanic Current.—To the galvanic current the auditory reacts by certain fixed laws.

This normal formula is as follows:

Ka S Kl, distinct accented sound.

Ka D Kl >, sound disappearing by degrees.

Ka O –, no sensation of sound.

An S –, " "

An D –, " "

An O Kl, weak and short sound, similar in character to Ka S.

In the above formula, Ka = Kathode (negative pole), An = Anode (positive pole), S = closing (Schliessung), O = opening (Oeffnung), D = duration of current.

Pf = whistling sound.

Kl = ringing "

Z = hissing "

The sensations with KaS appear sooner and stronger than with AnO.

This formula, it will be observed, harmonizes with the law of electrotonos and Pflüger's contraction law—that "a nerve is stimulated by the appearance of catelectrotonos and the disappearance of anelectrotonos; not, however, by the disappearance of catelectrotonos and the appearance of anelectrotonos."

Although the character of sounds varies with the strength and continuance of the current and with the individual, yet in the healthy ear the polar effects never vary.

There is never any sensation of sound with the closing of the anode (An S), except in pathologic conditions.

The polar effect is therefore the leading effect, and the direction of the current through the auditory nerve appears to have no demonstrable influence.

Both Brenner * and Erb,† by interposing the various grades of resistance in the circuit, extensively experimented along this line, and to these experiments we refer those interested in the matter.

We thoroughly agree with Brenner and Erb that the reactions of the auditory nerve are obtained by the direct action of the current on the nerve, and not by reflex action through the trigeminus. This view is proved by the general fact of the conductibility of the tissues of the brain, by the fact that even when the trigeminus is paralyzed the reaction may

* Op. cit., Band i., p. 105.

† Archiv. Ophthalmology und Otolog., vol. i., No. 1, p. 246.

yet occur,* and by the fact that when the electrode is placed in a condition favorable for the entrance of the current into the ear, the reaction is more decided than when the electrode is placed in a condition favorable for the excitement of the trigeminus, but unfavorable for the direct entrance of the current, as has been conclusively shown by Erb † and by ourselves.‡ We have removed the pole from the tragus to the malar bone and the cheek, both of which points are highly favorable for the excitation of the trigeminus, and have found that with removal the reaction diminished or disappeared.

In order to obtain that normal formula, the following conditions are necessary:

1. Convenient galvanic apparatus.

A very powerful galvanic battery is not needed. The strength of the current measured in milliamperes necessary for these investigations ranges between one and ten milliamperes, although it is seldom necessary or best to use more than three or four millimetres. There should be a current reverser; and a rheostat, though not exactly indispensable, is yet very convenient.

2. A right method of application, and practice in using it.

On the whole, the best method of application to produce these reactions is the external arrangement, in which one pole is firmly pressed on the tragus (the ear external auditory canal having been previously filled with warm salt water), while the other is held in or fastened on the hand on the opposite side. Any convenient electrodes may be used for these purposes. So long as the pole whose specific effect we desire to produce is on the right place in the ear or on the tragus, the position of the other electrode is not absolutely essential, provided it is somewhere on the opposite side, so as to allow the current to pass through the auditory nerve. It is difficult or impossible to get the reaction while the pole is on the mastoid process of the same side. It has been shown that when both poles are placed in the auditory canal, by means of a double electrode, the auditory nerve reacts to the nearer pole.

3. A number of intelligent and practised patients with both healthy and diseased ears.

The advantages of intelligence on the part of a patient are obvious; just as in investigating electro-muscular sensibility, it is necessary to depend entirely on the statements of the patient for our information. Even the strong-minded and intelligent are sometimes so distressed by the pain produced by the applications, or so distracted by the sensations of dizziness, and the contractions of the facial muscles, that they are unable to

* *Vide* Moos' case, above quoted in Archiv Opth. und Otol., vol. i., No. 2, p. 482.

† Archiv Ophth. und Otol., vol. i., No. 1, p. 261 et seq.

‡ For a detailed discussion of this subject, see Brenner's work, Band i., 1 Abth., p. 94 et seq.

rightly interpret their subjective sensations in the ear. It is necessary that the experiments should be made on a number of patients, in order to obtain the variety of reactions above described.

It is best also to make the first experiment on patients who have diseased ears, for it is as true of the auditory as of the nasal passages that they sometimes become less sensitive when diseased. This is to be explained partly by the manipulations and treatment to which such patients become accustomed, and partly by the fact that the morbid process itself produces callousness of the parts.

After the patient is in position, with his head inclined on the back of the chair or lounge, and one of the electrodes fastened to or held in the hand opposite the ear to be experimented on, a little warm salt water should be dropped in (which can be very conveniently done by squeezing the small quantity necessary to fill the external auditory canal from a small sponge or from a teaspoon or funnel-shaped glass *) and the other electrode firmly pressed on the tragus. It is well to begin with a small number of elements, and gradually increase until a reaction is obtained. The reaction will usually appear when the current is strong enough to produce contractions of the facial muscles. The patient should all the time be continually and repeatedly questioned in regard to the sensations experienced, especially if he is unaccustomed to the treatment, for at first he may be so distracted by the flashes of light before the eyes, the contractions of the facial muscles, the nausea, the metallic taste, and the noise of the water in the ear, and especially by the pain, that he may be unable at first to distinguish the true character of the reaction.

If the battery is provided with a commutator, for increasing and diminishing the number of elements brought into requisition, a current reverser for changing the direction of the current without removing the poles, and a rheostat for introducing resistances into the circuit, the labor of the operator will be materially lightened; but such appliances are not indispensable.

The operator should remember that the reactions are modified by the experiment itself. (*a.*) Ka S is most effectual after An S. Therefore the use of voltaic alternatives is of service.

(*b.*) The excitability of the nerve is increased by long closure of kathode (Ka S).

(*c.*) The excitement of An O increases with the strength of the current and the length of closure.

It should be remembered also that Ka S is stronger and quicker than An O.

Judging from our own researches in this department, these three leading statements of Brenner—that the auditory nerve reacts to the nearest

* It is well to place a towel about the neck, just as when syringing the ear, so as to avoid wetting the collar or other clothing of the patient.

electrode in a regular manner, that in health sounds of some kind are produced at the closing and in the duration of the kathode, and that in pathologic cases a part of the normal formula is more or less changed—are capable of sufficient and easy demonstration to those who are thoroughly familiar with electro-therapeutic experimentation.

On the other hand, some of the special features of Brenner's system offer difficulties in the way of their successful and uniform demonstration that can only be overcome by careful practice in this special department. To catch the sounds which in health are heard at the opening of the anode; to distinguish between the noise caused by the agitation of the water in the ear, and the subjective sounds that are so frequently the symptoms of disease of the auditory apparatus and the genuine reaction of the auditory nerve; to obtain the complete normal formula in health, and to satisfactorily discriminate between the various abnormal reactions of disease—the first attempt to fully corroborate all the assertions in these particulars will usually result in complete or partial failure, especially to those who are unfamiliar with the use of galvanic apparatus.

Degrees of Irritability.—Brenner distinguishes three different degrees of irritability of the auditory nerve, according to the number of elements that it takes to excite the reaction. The degrees of irritability may be changed during the sitting by the effect of the current on the nerve, and especially by the voltaic alternatives.

Thus, if at the beginning of the sitting the nerve reacted to a certain current strength, but to no less, then this current strength would represent the primary irritability of that nerve.

If by various alternations of the current the nerve is brought into a condition that it reacts to three milliamperes, these three milliamperes represent the secondary irritability of that nerve.

If, by still further excitation, the nerve is made to react to two milliamperes, these two milliamperes represent the tertiary excitability of that nerve.

In opposition to the above conclusions Dr. Wreden, of St. Petersburg, has made a number of experiments which seem to him to establish that the sounds heard during galvanization of the ear are due not to the reaction of the auditory nerve, but to the contraction of the small muscles of the middle ear. In his experiments he electrized the Eustachian tube, through the catheter, and also the middle ear, by means of small, delicate, and finely graduated sounds insulated to their points. He believes that by this method he causes contraction of the tensor tympani and of the stapedius, through irritation of the fifth and seventh nerves.*

Wreden asserts that during electrization by these methods the membrana tympani is retracted, and believes that this retraction is caused by

* A résumé of this subject is presented in Dr. Roosa's work on "Diseases of the Ear," pp. 493–495.

the contraction of the muscles. This, however, has been denied by Poorten. To settle this question, Löwenberg devised a manometer, which consists in a bit of cork or rubber fitted into the external meatus hermetically, and receiving hermetically a capillary glass tube which contains a drop of colored liquid. The external meatus is filled with water, which is connected with one of the poles of a faradic machine, while the other is applied to the skin by a sponge or through the Eustachian tube. When the membrana tympani is retracted by the action of the current, the drop of colored water indicates this retraction by falling; when it is pushed outward, by rising.

Admitting to the full all that has been claimed by Wreden and Löwenberg, we do not see that it proves that the supposed complex reactions of the auditory nerve to electricity are nothing more than muscular contractions. Admitting that in some cases where the membrana tympani is gone, the reactions are not obtained, still the following considerations are, to our mind, convincing:

1. The reactions of the galvanic current, when applied to the ear, are frequently similar to some of the sounds of tinnitus aurium. They are sometimes so much alike that they cannot be distinguished.

2. The differential polar effects of the galvanic current on the ear, which are very easy of demonstration, cannot be explained by any theory of muscular contraction.

3. Some of the reactions are produced by the steady action of the galvanic current, without any interruption, and with a strength not sufficient to produce muscular contraction; while it is true that certain reactions in some cases require strong and interrupted currents, it is not true of all of them.

4. A reaction of the auditory nerve similar to some forms of tinnitus can be obtained in some sensitive cases, not only by galvanization of the ear, but of the other parts of the head, and even the trunk.

We have had a patient who complained every time we galvanized the spine that buzzing, hissing sounds were excited in his ear. Similar sounds are produced by galvanization of the ear. The effect in this case was probably reflex.

All these considerations convince us that the variety of sounds produced by galvanization of the ear is due to the excitation of the auditory nerve, and that this excitation may be both direct and reflex. We are fully aware, however, that for the present this fact has a greater interest for the electro-physiologist than for the electro-therapeutist.

Olfactory Nerve.—We have observed in frequent experimenting on ourselves that the negative pole of a strong galvanic current applied to the Schneiderian membrane caused, in certain sensitive localities, an odor much resembling sulphuretted hydrogen. The odor observed in the neighborhood of docks will perhaps suggest the peculiar character of this reaction more than any formal description. This reaction is obtained only when a powerful current is used. It is obtained at the opening of the circuit, while the circuit is closed and for some little time after the circuit is opened. We have found that this peculiar reaction varies much with the individual, and with the same individual at different times. A sensitive, or even an ulcerated condition of the mucous membrane would seem to form it. Although we are frequently treating cases of rhinitis (nasal catarrh) by internal galvanization with metallic electrodes, yet our patients never speak of this peculiar odor. The mucous membrane of the nasal passages is very sensitive, and in ordinary therapeutic applications only gentle currents will be borne, whereas this reaction of the olfactory nerves demands powerful and painful currents.

The differential reaction of the positive and the negative pole of the ascending and descending currents that were long ago claimed by Ritter, we have not been able to confirm. The phenomenon of sneezing, or a disposition to sneeze, of which Ritter spoke, is due, not to any reaction of the olfactory nerve, but to the mechanical irritation of the sensory nerves by the electrode. Sneezing, as all aurists know, is called forth by a single introduction of the Eustachian catheter, and we observe it continually in introducing the nasal electrode. It is observed most, however, just as the electrode is being inserted; and when the current is running, the symptom does not usually annoy us. The action of a gentle current on the sensory nerves of the nasal passages seems rather to have a sedative effect, and in a measure counteracts the tendency to sneeze that is excited by the mechanical irritation of the electrode.

Schönbein suggests that the peculiar smell experienced from the passage of the electric current through the olfactory nerve is caused by ozone that is generated.

This peculiar odor, observed in powerful galvanization of the nasal passage, is unquestionably due to the reaction of the nerve to the electric stimulus, and corresponds to the effects produced by the same agent on the nerves of seeing, hearing, and tasting.

Franklinic electricity, electro-magnetism, magneto-electricity, are unable, in any strength that can be endured by a person in health, to excite the peculiar reaction of the olfactory nerve.

Action of Electricity on the Gustatory Nerve—Action of the Galvanic Current.—In 1754, long before the discovery of galvanism, it was noticed by M. Sulzer that lead and silver, when connected and then brought in contact with the tongue, gave rise to a peculiar taste similar to that produced by vitriol of iron. If we apply a piece of zinc to the upper, and one of silver to the lower part of the tongue, a powerful acid taste will be experienced under the zinc plate, and a slight alkaline taste under the silver plate. These sensations are perceived as long as the circuit is closed; but if the plate or the tongue be warmer or colder than natural, or very much benumbed by acids or other irritating substances, very little, if any, sensation is produced. If the tension of the current be much increased, by using several pairs, the tongue becomes convulsed and a flash of light is perceived. When neither of the electrodes touches the tongue, a metallic instead of an acid or alkaline taste is produced.

The peculiar reaction of the gustatory nerve to the current is generally described by those on whom we have experimented as "coppery," or "sour," or "metallic," or "bitter." Sour or coppery are, we believe, the designations most frequently employed by those persons who experience the sensation for the first time, and who have no theories in the matter to prove or disprove, and who therefore are likely to give their real impressions. If we ask them whether they have a taste in the mouth while the current is passing, they usually reply that the taste is sour or "coppery," and sometimes they may call it "bitter." If we ask them whether the taste is "metallic," they usually reply in the affirmative. Our observations on this subject have been very numerous, and they have been made with both currents. It is not necessary to send the galvanic current through the tongue or through the chorda tympani nerve, or through the face even; for galvanization of the neck in the anterior and posterior regions, and of the head in almost any direction, and of the spine—the lower as well as the upper region—will be felt in the gustatory nerve.

This metallic taste is felt almost as soon as the galvanic current is closed, grows stronger while the current runs up to a certain point, and is sometimes felt for several minutes after the electrodes are removed. In some temperaments on which we have experimented, the metallic taste remains on the tongue for several hours, and even all day, and longer.

In susceptible temperaments the faradic current produces in a less degree this metallic taste, and that, too, not only when applied to the tongue, but also the head, neck, and spine. In the operations of central galvanization this reaction of the gustatory nerve becomes of considerable value in showing us that the current is passing as we wish it, and that the patient is receiving all that is well for him. The gustatory reaction thus answers the purpose of a galvanometer, showing that the current is passing, and to a certain degree regulating the dose.

There is little doubt that this metallic taste, caused by electrization, is due to a peculiar excitation of the properties of the gustatory nerves by the stimulus of the current.

The theory that it might be of an electrolytic character, and therefore explained by the products of decomposition at the poles—acid at the positive, and alkalies at the negative—Rosenthal, by a variety of experiments, has shown to be untenable.

CHAPTER VII.

ACTION OF ELECTRICITY ON MOTOR AND SENSORY NERVES AND VOLUNTARY MUSCLES.

Irritability of nerves and muscles is that property by virtue of which they conduct the natural stimulus of the body, or external impressions, or respond to artificial stimulation.

Nerves and muscles are called irritable so long as they retain this property. Irritability of the nerves is a property inherent in them. No other tissue except nerve tissue possesses this property.

During life nerves and muscles manifest their irritability by fulfilling all the natural functions that belong to them; it is this property that enables them to conduct that mysterious vital agent, which, in lieu of definite knowledge, we are obliged to call nerve force. This nerve force, which is peculiar to living beings, may possibly be correlative to the other forces of nature—light, heat, electricity, magnetism, and gravitation—but the theory that it is identical with electricity is, as will be seen, untenable.

Irritability, How Long Retained after Death.—The irritability of nerves and muscles begins to diminish after death, and sooner or later disappears. It disappears much sooner in warm-blooded than in cold-blooded animals.

In warm-blooded animals, as the rabbit and the dog, the muscular current may disappear in half or three-quarters of an hour. In the limb of a frog that has been properly prote ted and under a cool temperature, it may remain for two, three, or even four weeks. It is on account of this persistance of irritability in frogs that they are so frequently chosen in electrophysiologic experiments. Irritability also varies with the temperature. It lasts longer in cold than in warm weather, and under extreme heat it remains but a short time.

The local application of poisons and powerful chemic substances, as extract of opium, acetates of strychnine, morphine, creasote, nitrate of silver, mineral acids, rapidly destroys the irritability.

How Muscular Contractions are Produced.—There are, then, two ways by which the muscles can be made to contract under electricity: (1) by acting on the motor nerves, and (2) by acting on the muscles themselves. There is, however, this interesting and important difference in the effect of electrizing the motor nerves and the muscles, that when the former are electrized all the muscles supplied by them contract, and when the muscles are electrized, only that muscle to which the electrodes are applied, or that part of the muscle between the electrodes, will contract. When direct applications to the muscle are made, the best contractions are produced by putting one electrode at each end. The muscular contractions produced by directly faradizing the muscle are due to the excitation of the muscle, and also of the intra-muscular nerve-fibres. The most powerful muscular contractions are produced by placing one electrode on the muscle, and the other at the point where the motor nerve that supplies it is most superficial.

Differential Action of Positive and Negative Pole in Producing Contractions.—Not only is there a difference in the degree in the opening and closing contractions of the faradic current, but there is also a difference in the action of the poles in producing contractions. When the interruptions are rapid, as in the majority of machines, the muscle does not have time to go through all the process of lengthening and shortening with each movement of the current to and fro, and consequently it is kept in the state of tonic contraction above described. If, now, one pole be placed on some indifferent point, while the other pole is placed over the nerve to be acted on, it will be found that the negative pole produces stronger contractions than the positive.

This experiment is easily made, and it is not difficult to demonstrate on one's self that this stronger action of the negative pole in producing muscular contraction is entirely independent of the direction of the current—is, in short, a polar effect. We have already seen that on sensory nerves the negative pole is more powerfully felt than the positive.

Simple Fluctuation in Strength of Current Sufficient to Produce Contraction.—In order to produce muscular contractions, it is not necessary that the current should be opened or closed. A moderate variation in the strength of the current—such as is obtained by adding one or more cells, or by uniting another and independent current in the circuit, or by taking off some portion of the current from the circuit—will cause muscular contractions. The contractions produced in this way are, however, less vigorous than those produced in closing and opening the circuit. It is to be observed, also, that the vigor of the contractions is proportioned to the suddenness of the closing or opening the circuit. This point is frequently forced upon our observation in the treatment of paralysis. If the electrodes are armed with large sponges, and are slowly applied over the muscles, with gradually increasing pressure, scarcely any contraction, or at least only a feeble one, is produced; but if the interruption be made in the metallic part of the circuit—in the electrode by an interrupter, or in the battery—the contraction with the same current will be very energetic.

By referring to Electro-Physics it will be seen that the law of muscular contraction under electrization follows the laws of current-induction.

Both contraction and induction occur when a change is made in the strength of the current by closing, opening, increasing, or diminishing.

Muscular Contractions More Vigorous when a Great Length of the Nerve is Galvanized.—The muscular contraction caused by galvanization is greater when a large than when a small extent of the nerve is included between the electrodes. It is not a difficult matter to demonstrate this fact. This experiment can be made on nerves of rabbits, dogs, frogs, or other animals.

Action of the Faradic Current.—The faradic current, when rapidly interrupted, as in most of the faradic machines, and applied to the motor nerves, keeps up a tonic contraction of the muscles supplied by these. This contraction is maintained so long as the current runs.

If a contrivance for making slow inductions be connected with the faradic machine, then the contraction of the muscles corresponds to the opening and closing of the current, and the opening contraction is stronger than the closing.

When the current of the secondary wire is closed by placing the electrodes on the skin, the current of the primary coil (extra-current) exercises a retarding influence on the secondary current, and then the closing contraction is rendered more gradual and gentle from nothing to the maximum.

When the current of the secondary coil is opened, the current of the primary coil (extra-current) does not exist, and consequently the current of the secondary coil is not retarded and goes rapidly from its maximum to nothing.

Differential Action of Primary and Secondary Coils.—Duchenne has stated with a measure of truth that the current of the primary coil (extra-current) of his apparatus has a more powerful effect on the sensibility and contractility of the organs beneath the skin, while the current of the secondary coil acts more powerfully on the retina and on the skin. The primary coil is composed of thick, short wire.

The secondary coil is composed of long and thin wire with many windings.

The differential action of the primary and secondary currents on the skin, muscles, and optic nerve is due to these two causes:

1. The primary current, circulating through a short, thick wire, has less tension than the secondary current that circulates through a long, thin wire, because tension is developed only in the presence of resistance. Since, now, the skin offers greater resistance than the muscles, the secondary current, by virtue of its greater tension, is able to penetrate it, and also to affect the optic nerve. But the primary current, having less tension, circulates in the skin but slightly. If, however, the skin is properly moistened, becoming thereby a fair conductor, the current, which is one of quantity, goes to the muscles beneath, which are good conductors, and on

these it spends its force. In other words, a current of low tension selects the best conductors, avoiding the poor conductors so far as is possible, while the current of high tension traverses also poor conductors.

2. The primary current moves in one direction, and has a mild electrolytic power, while the secondary current moves to and fro so rapidly that it cannot perform electrolysis.

Action of the Galvanic Current.—The interrupted galvanic current of moderate strength, if applied to a motor nerve, causes all the muscles supplied by that nerve to contract.

If the current be interrupted slowly, the contractions will be clonic, if rapidly interrupted, the contractions will be tonic. The violent contractions that occur at the moment of closing and opening the circuit of an intense current may be avoided if we begin with an extremely mild current and slowly and gradually increase its tension. By this method Ritter was enabled to pass through his own person, without experiencing either the closing or opening shock, the enormous current generated from a battery of two hundred elements.

Galvano-tonic Contractions.—When very powerful currents are applied continuously to the nerves, tonic contractions are produced during the whole time that the circuit is closed. Contractions thus produced were called by Remak galvano-tonic contractions. They are called galvano-tonic contractions to distinguish them from the clonic contractions produced by the faradic current. When the galvanic current is applied continuously to the surface of the body, by means of moist sponges, the galvano-tonic contractions increase in vigor, up to a certain point, the longer the electrodes are kept in position. This phenomenon is explained mainly by the fact that the skin becomes more moist as well as hyperæmic by the effect of the current, and thus becomes a better conductor for the electricity. With the faradic current this increase of effect is not so observable. The current required to produce galvano-tonic contractions is quite powerful and painful. The strength of current required will depend on the position of the nerve acted on, the length of nerve included between the electrodes, and the individual experimented on.

Effect of the Will in Opposing and Aiding Contractions Produced by Electricity.—The contractions produced by electricity can be materially aided or opposed by effort of the will of the person operated on. If a person whose muscles are being electrized concentrate his mind on the muscle that is subjected to the influence of the current, and simultaneously with the closing of the circuit wills to contract the muscle, the contraction will be more vigorous and complete than when the electricity is not so aided. The will co-operates with the electricity, and the two agents reinforce each other, and thus accomplish more than would be possible for either alone. This can be very conveniently demonstrated on the communis extensor of the forearm. In electro-therapeutics this co-opera-

9

tion of the force of will and electricity becomes of great practical value. It has long been known that paralytic patients of all kinds, even those of a cerebral chronic incurable character, can be greatly benefited by slightly concentrating the mind on the parts to be moved, as the fingers or toes, and resolutely willing to move them.

In practice it has been found that such treatment is of positive and permanent service.

The combination of the force of will with electricity is very much more efficacious than either when used alone. When a muscle becomes so diseased that the will is powerless to remove it, the electricity may contract it with ease. Where electricity alone causes feeble or imperfect contraction, electricity, co-operating with the will, may make the contraction vigorous and complete. In order to make experiments of this kind fully successful, it is necessary that the will and force should be concentrated simultaneously with the closing of the circuit; and yet experience shows that the effect of the electrization, if not too long continued, is to give tone to the muscle, so that it responds more readily to the will for several minutes, or even hours, after being subjected to the electrization. This is especially observed in muscles that are in a condition of paresis. In all these experiments much depends on the organic energy and grit of the patient. Conversely, it is found that by an effort of will the contraction of muscles induced by electricity can be, within a certain limit, successfully opposed. The experiment can be made on the communis extensor of the forearm without difficulty. A feeble current will cause this muscle to contract so as to bring up the hand and fingers; by an effort of the will this can be resisted so that the hand remains on a level, or nearly so. When very strong currents are used the will is completely overborne, and has no effect whatever.

Extent of Shortening of Muscle during a Contraction.—In the process of contraction muscles shorten in proportion to their length. The greatest possible shortening is obtained during tetanic or continuous contraction, and not during a momentary contraction. The maximum of shortening is reached, not suddenly, but gradually, and it does not long remain at the maximum even when the electrization is continued, but begins to lengthen at first rapidly and then more slowly.

The greatest amount of shortening possible to a muscle is three-quarters or two-thirds of its length.

In contraction the muscle becomes a little smaller in bulk. The cause of this is not fully understood.*

Immediate Strengthening or Restorative Effect of Electrization on Voluntary Muscles.—One very interesting effect of electrization on voluntary muscles is to increase their power of doing work. This effect, which is

* "Electro-Physiology and Electro-Therapeutics." By C. E. Morgan, M.D. New York, 1868, p. 573.

called by Heidenhain and Remak restorative, can be demonstrated in various ways. The capacity of walking, in cases of paralysis of the lower limbs, is sometimes increased at once after electrization; the patient steps across the floor easier and more firmly and rapidly, and can walk further; or he can raise his leg higher and with less difficulty. In one case of paralysis of the tibialis anticus muscle there was no reponse to the will until a current of medium strength had been applied, when it contracted without much difficulty. Dr. Poore * found, on placing a weight of 17 oz. in the hand of a man holding his arm out at right angles with his body, that in four minutes the pain was so great that he could not go on; applying now a mild current through the nerves of the arm, the strength returned. Another man could hold out his arm 13½ minutes when the current was applied, but only 6 minutes without the current.

The dynamometer is a good means of studying this subject. In one case Dr. Poore found that eight successive squeezes of the dynamometer with electrization gave 477 lbs.; without electrization, 388 lbs.; a difference of 89 lbs. In another experiment made, when the hand was not tired by previous experimenting, the difference was even more marked, being a gain of 152 in six squeezes of the dynamometer.

Effect of Fatigue of Muscles on the Contractility.—When a striped muscle becomes very much weakened or fatigued it behaves under electrization much like the smooth muscle. We have demonstrated this fact on dying rabbits and dogs. Beginning the electrization just as they are cut open, the striped muscles react vigorously and normally to the current; but as the animal dies the character of the contraction changes, becoming slower and more deliberate. If, now, the current be rapidly interrupted, no contraction occurs, for there is not time for the muscle to respond. If, now, weak currents are used, the muscle contracts very much after the manner of unstriped muscle—that is, with a slow drawing rather than a rapid and vigorous action.

Effect of Muscular Tension and Relaxation on Muscular Contraction.—Dr. Wm. R. Fisher, of New York, has called attention to the fact that muscles contract more easily when somewhat relaxed than when in a tense condition. This experiment can be tried very easily on the common extensor of the forearm or on the peronei muscles of the leg. The fact is of practical importance in the treatment of paralysis.

Ziemssen,† on experimenting with unpolarized electrodes, and gradually increasing the strength by the aid of the rheostat, obtained the following results:

1. With the weakest current that caused muscular contraction there was opening contraction at the negative pole.

2. With a current a little stronger there was strong closing contraction at the negative pole, and weak opening contraction at the positive.

* The Practitioner, January, 1873.

† Op. cit., p. 80.

3. With still stronger current there was also weak contraction at the opening of the positive pole.

4. With still stronger currents there was a tonic contraction at the negative pole, continuing for some time after the contraction at the closing.

5. With a much stronger current the tonic contraction was more vigorous; the other contractions are also increased in strength, and there appeared a contraction at the opening of the negative pole.

6. With the strongest current that can be borne, all the other contractions were increased in strength, and there appeared, besides, moderate tonic contractions at the positive pole.

The above results can be verified only when unpolarizable electrodes are used, for with ordinary electrodes the pain would be far too great to be endured. The opening and closing of the current must be made in the metallic part of the connection, in order to give it the greatest possible suddenness. Ziemssen suggests for these experiments the median and ulnar nerves at a point a little above the wrist. At this point the epidermis is quite thin and the nerves superficial. Judging from our observations, it is impossible to reduce this subject to a rigid mathematic law. The words "strong" and "weak," as applied to currents, are quite indefinite, and the irritability of nerves varies in different individuals at different times. It is for these reasons that observers have in the past so differed in the results of their experiments.

Electro-muscular Contractility and Electro-muscular Sensibility.—The susceptibility of the muscle to contract under the influence of the electric current is called electro-muscular contractility. The sensation that accompanies this contraction of the muscles under the electric influence is called electro-muscular sensibility. Electro-muscular contractility and electro-muscular sensibility vary in different individuals, and in different parts of the body. They are greatly modified by disease. This fact is of great importance in diagnosis of paralytic affections.

In using the terms electro-muscular sensibility and electro-muscular contractility, we do not wish to convey the idea that they represent any special nerve-functions, but rather that the general sensibility of the nerves and the general contractile power of the muscles may be excited by the application of electricity. The question, whether there is any special sense of muscular contractility, aside from the general sensibility of the nerves, of the muscle, of the tissues that surround it, and of the bones and cartilages with which it is connected, is one that we are disposed to answer in the negative. The pain or sensation accompanying muscular contraction is very different in character from that resulting from electric irritation of the skin. It is a dull, tensile sensation, that becomes exceedingly painful under strong currents.

The manifestations of the electro-muscular contractility and sensibility of the muscles in the different parts of the body are modified, first, by the anatomical position of the muscles; secondly, by the quantity and distribution of the sensitive nerves; and thirdly, by the thickness of the skin and adipose tissue.

The muscles of the face, the platysma myoides and sterno-cleido-mastoid are, in health, very sensitive to the electric influence. Next in order of sensitiveness to the electric current are the anterior muscles of the forearm and of the inner side of the thigh. On the other hand, the muscles of the back possess a much less degree of electro-muscular contractility and sensibility, and the posterior muscles of the forearm and posterior and other muscles of the thigh are much less susceptible to the electric influence than those of the anterior and inner portions of these limbs. In corpulent patients it is more difficult to affect the muscles, because adipose tissue is comparatively a poor conductor. In women and children the adipose tissue is relatively more abundant than in males and adults.

Increase of Temperature after Muscular Contraction.—It has been ascertained by careful experiments, that an increase of temperature results from muscular contractions produced by the electric current. Increase of temperature in the muscles of paralyzed limbs, after electrization, is frequently perceptible to the touch of the operator, and the sensations of the patient. We have repeatedly demonstrated the same results from faradization of the arms, the legs, the face, and, indeed, all parts of the body. In very many cases this increase of temperature is so marked as to be powerfully appreciated by the patient, and entirely perceptible to the hand of the operator. General faradization causes more or less elevation of the temperature of the body. This is demonstrated by the sensations of the patient,* and by the thermometer.

It has been shown by Brown-Séquard and Lombard that excitation of the nerves of the skin causes an increase of temperature in the limb.†

The development of heat is not aided by increasing the strength of the current above the degree necessary to produce a full contraction. It has been demonstrated that, in patients afflicted with traumatic tetanus, there is a great increase of temperature that remains for some time after death. Investigations on the effect of muscular contraction on temperature should be made by delicate surface thermometers. Some of the superficial muscles of the forearm offer a g od surface for this experiment. The thermometer must be kept firmly and uniformly pressed on the skin, and the modifying effect of currents of cold air should be guarded against. The thermometer should be kept *in situ* for about fifteen minutes before beginning electrization, so as to get accurately the normal temperature. Then the nerve that supplies the muscle or muscles to be tested should be faradized.

* "Electricität in der Medecin," 1866, p. 29.
† Archives de Physiologie, November and December, 1868.

The general results of all the investigations that have been made in this department are these:

1. When muscles are made to contract under faradization of the nerves that supply them their temperature rises.

2. This elevation of temperature is not necessarily accompanied by any increase in size of the vessels, although faradization usually increases the size and appearance of the vessels more or less.

3. The more vigorous the contraction and the longer it is continued, the higher the temperature rises.

4. If the faradization be continued long enough the temperature will be so much increased that it can be detected without difficulty by the hand, and by the sensations of the person operated on.

5. When all the superficial muscles of the body are faradized, as in the method of general faradization, the temperature not only of individual muscles, here and there, but also of the whole body, rises. This fact we have repeated and demonstrated by observations made on many varieties of temperament.

A more accurate method of investigating this subject is by means of the thermo-electric pile. This instrument is capable of measuring a small variation in temperature, and also indicates the variations much more quickly than the thermometer. The thermo-electric pile is connected with a reflecting galvanometer. Ziemssen gives the following observations made on the extensors of the forearm:

Time of Faradization. Minutes.	Seconds.	Deflection of the Needle of the Galvanometer.
0	15	− 1.5
0	30	+ 2.3
0	45	+ 5.0
1	..	− 7.2
2	..	+ 19.0
3	..	+ 30.1
4	..	+ 40.2

It will be observed that with the increase in the time of the faradization there is greater and greater deflection of the needle, just as there is a rise of the mercury in the ordinary thermometer.

Source of Heat in Muscular Contraction.—According to Hermann,* who has specially studied the chemistry of the development of heat during muscular contraction, muscular work is the result of the decomposition of nitrogenous substances. Among the products of this decomposition are a fixed acid, carbonic acid, and myosine. Of these the carbonic acid leaves the body, while the fixed acid and the myosine remain and are worked over again in the organism. The muscles grow at the same time that they work and develop heat, and urea and creatine are found in the residuum.

* Morgan, op. cit., p. 582 et seq.

The muscle is restored by the action of oxygen, an albuminoid, and a non-nitrogenous substance in the blood.

All these complex chemic changes that are excited during muscular contraction give rise to heat. If the muscle is prevented, by mechanical means, from contracting, the heat develops in it more rapidly than when it is free. This follows from the recognized law of the correlation and conservation of forces. The force that does not appear as work appears as heat.

Duration of Electro-muscular Contractility after Death.—The muscles retain their contractility under electricity several hours after death. The length of time that the electro-muscular contractility is preserved varies with different muscles, with different animals, and probably, also, with the mode of death. In order to determine this question, we have made experiments on dogs and rabbits. Dr. Onimus,* of Paris, has experimented on the body of a murderer who had been guillotined. He found that the muscles of the tongue and diaphragm were the first to lose their electro-muscular contractility. Next came the muscles of the face, among which the masseter retains its excitability the longest. Two and a half hours after death the electro-muscular contractility was lost in all these muscles.

In the limbs the extensor muscles first lose their electro-muscular contractility, and in about an hour the flexors followed. The muscles of the trunk responded five or six hours after death, and the abdominal muscles longer still.

Onimus observed on the criminal what we have observed on dogs and rabbits, that when the muscle is dying it contracts most noticeably at the point where the electrodes are placed, and very slowly at a distance from the electrodes; and that the muscles respond to direct electrization with needles after they have ceased to respond to the current when applied through the skin.

Previously, in January and February, 1802, Aldini, a nephew of Galvani, obtained permission from the government to experiment on two criminals who were executed at Boulogne. Immediately after death the bodies were submitted to powerful galvanic excitation. The muscles of the face contracted vigorously in such grimaces as to frighten the assistants. The limbs were violently convulsed, and the bodies acted as though they would rise again to life.

At Glasgow, Ure made similar experiments on the body of a criminal that had been on the gallows one hour. The applications were made to the spinal marrow, the phrenic nerves, and the intercostal muscles. According to the position of the electrodes the body was bent forcibly back, the chest rose and fell as in the act of breathing, and the various emotions of rage, terror, despair, were depicted on the countenance. One of the spectators fainted, and several were obliged to leave the room.

* I e Mouvement Médicale, Feb., 1873.

Electro-physiologic Anatomy.—Electro-physiologic anatomy treats of the physiologic action of muscles under the influence of the electric current applied in such a way as to produce contractions.

The contraction observed in an individual muscle, when submitted to the influence of the electric current, closely resembles the contraction of the same muscle when under the influence of the will.

Duchenne was the first to investigate this subject systematically, and his researches have done much to modify the accepted views concerning the functions of certain muscles. Those who desire a more complete idea of his views than is given in the following brief *résumé*, we refer to his writings.*

Muscles of the Face—Electro-physiognomy.—This name has been applied to the study of character and expression, through localized faradization of the muscles of the face. By means of small electrodes the current can be localized so as to produce contractions even in the smallest muscles. For these experiments a recently dead subject has this advantage over the living man, that in the case of the latter contractions produced by the current would be complicated and interfered with by involuntary movements.

According to Duchenne, who has chiefly investigated this subject, the frontalis muscle, when a little contracted, expresses pleasure; when more contracted, astonishment or doubt; when strongly contracted with other muscles, terror.

Contraction of the pyramidalis nasi expresses sadness; of the corrugator supercilii, contemplation; of the orbicularis palpebrarum, contempt. Contraction of these two, united with the pyramidalis nasi, gives a hateful malicious expression. Contraction of the triangularis nasi expresses lust; of the zygomaticus major, various degrees of mirth; of the zygomaticus minor, melancholy; of the platysma myoides, hypocritical laughter; of the platysma myoides, pain. Contraction of the platysma myoides and frontalis gives an expression of terror. Contraction of the platysma myoides and pyramidalis expresses rage. United contraction of the zygomaticus major and frontalis produces an expression of agreeable surprise. Contraction of the buccinator indicates age, by making furrows in the cheek.

Contraction of the levator alæ and labii superioris causes an unpleasant expression, such as a child exhibits when about to cry; contraction of the triangularis oris gives an expression of sadness or disgust.

Contraction of the external fibres of the orbicularis oris gives the lips a

* "De l'Electrisation Localisée et de son Application à la Pathologie et à la Thérapeutique." Paris, 1861. Also, "Mécanisme de la Physionomie Humaine, ou Analyse Electro-physiologique de l'Expression des Passions applicable à la Pratique des Arts Plastiques." Paris, 1862. This work contains photographic representations of the various appearances of the face under electrization of the different muscles. These photographs are frequently referred to by Darwin in his work on "Expression."

position of whistling or kissing; contraction of the internal fibres of the same muscle compresses the lips against the teeth.

Muscles of the Upper Extremity.—The contractions resulting from electrization of the extensors of the fingers give to the hand a peculiar appearance.

The first phalanges not only become extended, but are spread apart, while the last two phalanges become flexed.

The metacarpus forms an angle with the forearm, and in this condition the hand resembles, to a certain extent, a bird's claw.

Electrization of the extensor digiti minimi proprius separates the little finger from its neighbor, while contraction of the extensor indicis proprius brings the index and middle finger together. By the method of localized electrization the adductors and abductors of the fingers, and the interossei and lumbricales, are found to act not only in drawing these members together and separating them, but also in extending the second phalanx of the thumb and the second and third of the other fingers.

The flexor pollicis brevis is concerned in extending the second phalanx of the thumb, as well as in flexing the first.

So long as the arm is in its natural position, the supinator longus has no function to perform; it is only when the forearm is prone that its peculiar action is manifest.

In paralysis of any one of the above muscles, it is readily seen that the observation made concerning their function is correct.

For example: if the adductor longus and extensor brevis pollicis become paralyzed, the metacarpal bone of the thumb is adducted. If the extensor longus pollicis is paralyzed, the thumb is inclined toward the metacarpus, although its movements are not markedly impaired if the extensor brevis and adductor longus are strong.

Electrization of the deltoid not only raises the upper arm, but also very perceptibly changes the position of the scapula. The external angle of the shoulder-blade becomes depressed, the internal angle is elevated, while the distance between its posterior spinal border and the ribs is slightly increased. In paralysis of the deltoid the arm hangs by the side almost completely helpless. The muscle is composed of three distinct groups of fibres, and the degree of paralysis depends upon the number of groups or special group involved.

The pectoralis major and latissimus dorsi muscles, although situated for the most part on the trunk of the body, are especially useful in assisting in the movements of the arm.

Muscles of the Trunk.—When all of the fibres of the trapezius are submitted to electric excitation, the shoulder-blade becomes elevated, its posterior border approaches the median line, the shoulders are drawn backward, and the head is thrown slightly forward and toward the opposite side. Like the deltoid, the trapezius is made up of three sets of fibres.

When the superior set is electrized the head turns toward the side irritated, and the face looks toward the opposite side.

The middle set of fibres elevates the shoulder-blade, while by the action of the lower set its inner angle is depressed, and its posterior border is drawn toward the median line. In complete paralysis of the trapezius the following symptoms are manifest: The back is rendered broader, on account of the scapula removing slightly from the spinous processes; the shoulder becomes depressed, and, on account of the absence of steady support for the arm, its movements are rendered difficult. Electrization of the rhomboideus major and minor muscles elevates the scapula and slightly turns it on its outer angle.

If the current be sufficiently intense, the lower angle of the scapula approaches nearer to the spinous processes than the inner.

If the rhomboideus muscles are paralyzed, the scapula removes itself somewhat from the walls of the thorax, the skin between the shoulder-blade and the spine appears in folds, and the lower angle of the bone is drawn forward and outward, on account of the action of the serratus anticus major. By excitation of the serratus anticus major the scapula is drawn forward and outward, so that the space between its posterior border and the spine is doubled. The posterior border is pressed against the ribs, while the anterior border is markedly removed from them.

When the muscle is paralyzed the shoulder-blade sinks but little, so long as the arm hangs motionless by the side; but as soon as it is moved from the body the posterior border and under angle of the scapula are lifted from the thorax, while the anterior approaches it more closely. In complete paralysis of the serratus anticus the movements of the arm are much impaired.

A single external intercostal muscle may be electrized by pressing a small electrode against the lower border of one of the upper ribs, near the origin of the serratus magnus muscle.

The individual abdominal muscles are readily influenced by electric excitation.

Electrization of the rectus muscle so stretches and draws it inward that the abdominal wall becomes flat. Irritation of the external oblique expands the abdomen laterally.

If we electrize the transverse abdominal, powerful transverse contractions of the abdomen follow. When both phrenic nerves are submitted to electric excitation, powerful and frequent contractions of the diaphragm are produced. An increased amount of air rushes into the lungs, on account of the capacity of the thorax enlarging through the descent of the diaphragm, and the moving outward of the false ribs. Atrophy of the diaphragm causes, during inspiration, a depression of the epigastrium and abdominal walls, while the thorax expands as usual.

Muscles of the Lower Extremities.—Electric excitation reveals the fact that flexion and extension of the foot cannot be produced by the flexor or extensor muscles alone, since these muscles tend to abduct and adduct as well as flex and extend. The flexors and extensors cause direct flexion and extension only when they act in conjunction with certain other muscles.

The movements of the foot are controlled by four sets of muscles. These are:

The tibialis anticus, which at the same time flexes and adducts the foot—the flexor adductor muscle, the extensor digitorum communis longus and extensor hallucis, which flex and abduct the foot—the flexor abductor.

The gastrocnemius solius and tibialis posticus, which extend and adduct the foot—the extensor adductor, and the peroneus longus and brevis, which extend and abduct the foot—the extensor abductor.

Electrization of the tibialis anticus, or, in other words, the flexor adductor muscle, not only extends and adducts the foot, but lifts the inner border of its upper portion as well.

Electrization of that group of muscles called the flexor abductor, besides flexing and abducting the foot, extends the four last toes, lifts the outer border of the foot, turns the sole outward, and bends the great toe.

Pes equinus may result from the stronger action of the extensors.

If the flexor abductor group become paralyzed, the movement of the foot is reversed—the sole turning inward and the anterior portion turning upward.

Electrization of the extensor adductor group so extends and adducts the foot that the heel is directed outward and the great toe inward. The first phalanges of the toes become extended, and the last flexed, giving to them the form of claws.

Electrization of the extensor abductor so extends and abducts the foot that the internal malleolus becomes decidedly prominent through the sinking of the inner border and the elevation of the outer border of the foot. Paralysis of this last-named group of muscles produces in the course of time what may be termed a flat foot. This results from the disappearance of the arching of the foot.

In consequence of paralysis of the extensor adductor the foot naturally becomes abducted, the arch of the dorsal surface is increased, and instead of the flat foot above mentioned, we have a very decided hollowing out of the plantar side.

CHAPTER VIII.

ACTION OF ELECTRICITY ON INVOLUNTARY MUSCLES.

Contractions are produced in a voluntary muscle the instant the poles of a galvanic battery, or of an electro-magnetic machine in operation, are applied to it. The contraction of the muscle continues during the passage of the faradic current, but when the galvanic current is used quickly relaxes after the first shock. When, however, the intestines, the stomach, the œsophagus, and other parts which are composed of involuntary muscular fibre, are subjected to the electric current, movements are not induced in them until a certain time after the tissue has been acted upon. The movements thus excited continue for a time after the cessation of the current, and do not, as in the case of voluntary muscles, at once return to their normal condition.

Iris.—Faradization of the iris, with a very gentle current in a room that is moderately darkened, causes it to be constricted or dilated, according to the position of the electrodes.

Stomach.—Faradization or galvanization of the stomach causes gradual shortening of the transverse and longitudinal fibres in the direction from the cardiac to the pyloric orifice. In the treatment of paralysis of the œsophagus associated with a sort of atony of the stomach, we have frequently had occasion to observe the readiness with which this phenomenon is demonstrated in the living man by applications directly to the mucous surfaces of the parts.

Intestines.—If finely pointed electrodes or needles, connected either with a faradic or galvanic apparatus, be applied to the intestine of a living or recently killed animal, steady and firm contraction takes place at the points where the electrodes are applied. Under a mild current the contraction is slow, steady, and gradual. The intestines are drawn up after the manner of a woman's work-bag. This contraction, though most marked just at the point where the needles touch the intestines, is also observed a little distance between and on the outer side of the needles. Under strong currents this constriction takes place very rapidly, and goes on until the calibre of the intestines is nearly closed. When the electrodes are removed this constriction slowly disappears. These phenomena are seen both in the large and small intestines and in the rectum. The duodenum responds most readily, the rectum and colon less so. These phenomena are more or less modified by the condition of the animal, whether living or dead, and whether recently or long killed. This fact of electro-physiology, which has been frequently demonstrated on animals, is very suggestive in a practical point of view. The value of electricity in constipation is, in view of these observations, partially explained. Whether percutaneous electrization (both poles placed externally) or direct electrization (one electrode in the rectum or stomach and the other externally) effectually contracts either the muscular coats of the stomach or intestines, is a question upon which there is more or less disagreement. During the electrization of a hernia, Von Ziemssen * observed very positive contraction of the intestines. Kussmaul † speaks of the quickened peristaltic waves on a dilated stomach during direct electrization. The consensus of opinion, indeed, seems to be that in the methods of percutaneous and direct electrization enough current reaches the muscular coats of the stomach and intestines to influence their peristaltic movements. Meltzer,‡ on the contrary, experimenting, however, only with the faradic current on rabbits, dogs, and cats, comes to the conclusion that neither percutaneous nor direct faradization of the stomach or intestines produces any contraction in these parts. This subject in its relation to therapeutics is further considered in the chapter on Diseases of Digestion.

Spleen.—When the spleen of certain animals, living or recently killed, as the dog, is submitted to the action of a tolerably strong current, either faradic or galvanic, a visible drawing and contraction occur throughout the entire extent of the organ; not only where the electrodes are applied, but between them and beyond them, in every direction, there is manifest shrinking of the tissues, with change of color. This fact, which has been disputed by some physiologists, we have demonstrated in a variety of experiments. The phenomenon is not so noticeable in the spleen of the rabbit as in that of a dog, and in order that it may occur rapidly and be easily seen, the current used must be of considerable strength. The shortening and discoloration of the spleen under electrization appear to be more or less permanent. This physiologic fact suggests the query, whether the enlarged spleen of intermittent fever might not be treated by electricity.

Bladder.—When the filled or emptied bladder of a living or recently killed animal is acted on by either current, of moderate strength, a visible drawing and contraction take place in various directions. The tissue becomes firmer and harder, the cavity diminishes, and if it contains urine a portion of it is expelled. This electro-physiologic fact is utilized in cases of paralysis of the bladder.

* "Die Electricität in der Medizin," 4 Aufl., 1892.

† Archiv für Psychiatrie, Bd. viii.

‡ "An Experimental Study of Direct and Indirect Faradization on the Digestive Canal," 1895.

Uterus.—The uterus of animals and of the human being contracts after the manner of the intestines, bladder, and other involuntary muscles. Whatever pole is used, or in whatever direction the current be applied, contraction takes place whenever the current is applied, whether the uterus is or is not in a gravid condition. Both faradization and galvanization have this slow contracting influence on the uterus.

In the chapter on Diseases of Women, the very interesting and important practical applications of this physiologic fact will be pointed out in detail. It applies especially to the electric treatment of metritis and uterine engorgements.

Ureters.—The ureters are constricted and shortened by electrization, and as in the case of the uterus, the intestines, and the spleen, the contractions take place, according to the law of their physiologic action, from the kidneys toward the bladder, and the contractions continue after the electrodes are removed.

Vas Deferens, Epididymis, and Tunica Vaginalis.—When the electric current is applied to the vas deferens, the epididymis, or the scrotum, they likewise contract after the manner of the intestines, uterus, and so forth. The scrotum contracts rapidly, almost instantaneously, under a strong current, and remains contracted for some time, as we have demonstrated on rabbits and dogs, and on the living human being.

Gall-bladder.—When a current of considerable strength is applied to the gall-bladder by pointed electrodes, constriction takes place at the points of application, and the whole bladder tends to contract, and, like the urinary bladder, to discharge its contents. It is not impossible that a powerful current sent through the liver of the living subject, by external applications, may cause contraction of the gall-bladder; and in this way we may in part explain the value of electric treatment in jaundice.

Œsophagus.—In rodents the œsophagus consists of striped muscle only; in birds it consists of unstriped muscle, and in man of a combination of both striped and unstriped muscle. Both sets of fibres, longitudinal and circular, contract under the current, not only at the points where the electrodes are applied, but through the whole length downward toward the stomach. In the treatment of dysphagia this fact may well be considered.

Heart.—The effect of electrization of the pneumogastric and other nerves that supply the heart has already been considered. The effect of direct electrization of the tissue of the heart itself is not without interest. Galvanization, with currents of moderate strength, of the heart of an animal that has stopped beating, may cause a return of its rhythmical action. It has been sometimes observed that the contractions return more vigorously in the right than in the left side. According to our observation, in the hearts of dogs and rabbits much depends on the strength of the current used. If a strong current be directed through pointed electrodes to the substance of a heart of a dying animal, the pulsations are in part arrested, but they recur as soon as this current is broken. These conclusions are based on a large number of observations. When the heart has fully stopped it may be restored by a weak current, and again arrested by a strong current.

Blood-vessels.—The small arteries that contain considerable unstriped muscle contract under the current, after the manner of the intestines; that is, the contraction does not appear instantaneously, but a little time after the needles are applied it goes on slowly, and after the needles are removed they gradually return to their normal condition. In the larger arteries this contraction is not so marked.

It will be observed that electricity acts on unstriped muscular fibre, in this respect at least, very much like ergot. The power of ergot to constringe the blood-vessels is the explanation of its great value as a remedy in spinal and cerebral congestion. The efficacy of electrization in the same affections, as well as in sprains and various local inflammations, may be in part explained by the same theory. This subject will be discussed in the chapter devoted to the Influence of Electricity on Nutrition.

The above conclusions are based largely on our own experiments, although many of the observations had been previously made by various physiologists.

There were, however, certain queries in regard to the differential action of the poles, and of the two currents, and of weak and strong, on involuntary muscle, that had not been answered. These queries we have aimed to solve by a large number of experiments on animals. The records of one set of these experiments, noted at the time by our friend Dr. John Van Bibber, of Baltimore, are herewith presented. It will be observed that the chemic and other effects of the current, besides the contracting influence, are noted.

Experiment 1.—The abdominal cavity of a good-sized rabbit was opened, and a medium faradic current, with needle electrodes, was applied to the upper part of the small intestines. Contraction produced most vigorous at the positive. A vermicular motion was also observed not only in the part within the circuit, but extending some distance beyond each pole. The rabbit was fully under ether, and the only other muscular movements were cardiac and respiratory. The color of intestines was normal and healthy, and was undisturbed during this operation.

Experiment 2.—A galvanic current was now applied, with needle electrodes, a little below point of first experiment. There was an immediate change in the circulation of the part. It became darker and venous in its appearance, presenting the appearance of a clot. The intestines, before so flaccid as to render the insertion fo a needle difficult, became very full and hard. The negative pole was loose in the tissues, with bubbles of hydrogen generated around it, and, on the other hand, the positive pole became very firm in its insertion, with evident constriction of muscular fibre around it.

The first effect, therefore, seemed to be congestion, and afterward coagulation.

Experiment 3.—On stomach, with galvanic current. In region of positive pole the circular fibres are much contracted, and the same disintegrating effects of negative pole were observed.

Experiment 4.—Faradic current on large intestine. Contraction of muscular fibres was observed, and thought to be greater at positive pole.

Experiment 5.—Faradic current on spleen. The smooth surface of that organ was soon corrugated, tending to show that the tissues were contracting under its influence.

Experiment 6.—Galvanic current on spleen. Generation of hydrogen at negative pole, also congested appearance, and after removing needle very dark spot at negative pole.

Experiment 7.—Faradic current on bladder. The bladder was partially filled with urine, and when the current was applied there was great and immediate contraction of muscular fibres and expulsion of urine.

Experiment 8.—On left kidney, faradic current. Muscle contracted, and seemed to be permanently so, at least during observation.

Right kidney, galvanic current. Same effect at negative pole, dark congested spot; but during passage of current the bladder, which had been much contracted by faradic current, seemed to fill up.

Experiment 9.—On liver. No action. The rabbit seemed to show remarkable vitality, and it was necessary to renew ether very frequently. It was determined then that the electricity seemed to prolong life, even after it had been so taxed by anatomic mutilation.

The conclusions from a large variety of experiments, of which the above is a fair illustration, are these:

1. Both currents—faradic and galvanic—cause an unstriped muscle to contract in accordance with the law of its physiologic action. It remains contracted, and after the breaking of the current gradually returns to its normal condition.

2. The time when the contraction begins, and the vigor with which it continues, and the rapidity with which it returns to its normal condition, after the breaking of the current, varies with the organ acted on, with the strength of the current, and with the condition of the animal acted on, whether living, dying, recently or long dead.

3. The positive pole has a more powerful contracting influence on unstriped muscles than the negative. The differential action of the poles is seen in both currents, but is more decided with the galvanic. This fact we were, we believe, the first to discover. This fact of the more potent action of the positive pole on unstriped muscle is of considerable signification in the treatment of engorgements of the uterus, etc.

4. Unstriped muscles can also be made to contract by faradization or galvanization of the nerves and nerve-plexuses that supply them—indirect electrization.

5. The behavior of the different organs that are supplied with unstriped muscles under electrization depends on the relative amount of muscle in their tissues. The intestines, the scrotum, contract rapidly and vigorously; the spleen and arteries less perceptibly and more slowly.

The liver and lungs do not apparently contract under either current. The electrolytic action of the current is observed in these organs, as in all other tissues.

6. The differential reaction of voluntary and involuntary muscle to the current is mainly a matter of degree. Both kinds of muscle contract in accordance with the law of their physiologic action, under both currents, and both return to their normal condition; but involuntary muscle returns very slowly, while voluntary muscle returns rapidly, almost instantaneously. When voluntary muscles have become greatly exhausted through fatigue or death, they behave very much like involuntary muscles.

CHAPTER IX.

ACTION OF ELECTRICITY ON THE BLOOD.

The action of the galvanic current on the blood is a subject to which we have given at different times considerable attention. Blood coagulates so quickly after leaving the living body, that the action of electricity upon it can only be studied with satisfaction when the electrodes are placed within an artery or vein, or in a current of blood as it flows from the wounded blood-vessels before the process of coagulation has set in. We have experimented on blood with the galvanic current in both ways.

When the needles connected with the poles of a galvanic battery are inserted into the feebly flowing blood of a wounded animal, electrolysis at once takes place with differential polar action of a striking character. At the positive pole a small, firm, and dark clot forms, that adheres closely to the needle, especially if it be steel that is readily oxidized. At the negative pole a larger, softer, lighter, yellowish clot forms, with a mixture of foam or froth from the bubbles of hydrogen.

If the current be strong, and the operation protracted, the positive steel needle will become either destroyed by oxidization or greatly reduced in size.

From this it will be seen that the action of electricity on the blood is mainly, if not entirely, of a chemic character—in a word, electrolysis, or electro-chemic decomposition. Golubew and Burdon Sanderson have studied the effect of faradization on the blood-corpuscles under the microscope, and Rollet and Neuman have studied the same under the influence of the galvanic current. It has been shown that the red corpuscles of the blood are discolored by the alkalies of the negative pole, and caused to shrink by the acids at the positive pole. Under the discharges of the Leyden jar the red corpuscles change their shape and lose their color.

In order to determine the differential action of the poles in producing a clot, we have made a number of experiments on dogs. One method of experimenting was to etherize the animal, open the abdomen through the linea alba, and expose the aorta, into which needles, insulated with hard rubber up near to their points, and connected with both poles, were introduced. In some cases the artery was constricted, in others not. We condense the record of the experiments from the published statements of Dr. Keyes, who co-operated with us.

Experiment I.—March 17th. A small dog was etherized, the abdomen laid open through the linea alba, and the aorta exposed. Positive and negative needles, insulated (imperfectly) with hard rubber, were introduced into the aorta about one inch apart. Both needles were of steel, gold plated at the points. The negative needle was accidentally run through the artery, and emerged into the muscle beneath. The current from sixteen cells of a Stöhrer's battery was passed for ten minutes. The artery was not compressed. Blood flowed through it at great force.

Result.—Bloody foam surrounded the negative needle, the blood emerging from the artery. Needle loose. It dropped out, the blood followed.

Positive needle adherent to artery, requiring a little force to pull it away. Artery was cut, before the needle was removed, to look for clot. No clot discovered in the vessel. A little black material was found adherent to the wall of the artery, and to the positive needle at the point of entrance. The lining membrane of the artery was altered and discolored, wherever either needle had touched it, over a space about one and a half lines in diameter.

Experiment IV.—Medium-sized dog etherized. Positive needle (platinum), insulated with hard rubber, was placed in the artery. Negative needle (platinum), insulated with shellac, in muscles near the spine. Eighteen cells Stöhrer. Time, ten minutes. Current of blood about three-fourths, arrested through the artery, by compression with thumb and fingers, one inch above and below the needle.

Result.—Firm black clot outside of the vessel at point of the entrance of needle, and where the opposite wall was touched by the needle's point. Inside—firm, black clot, adherent to the wall, but not large enough to obliterate the vessel.

Lining membrane of artery blue-black, and coats of vessel adherent and condensed at point of entrance of needles, and where opposite wall had been touched. Needle not much acted upon. A little flake of hard rubber came off, and was left attached to the clot. A few bubbles of oxygen escaped from the vessel alongside the needle.

Experiment VII.—Positive needle gold, non-insulated. Negative needle steel, non-insulated. Both in vessel. Sixteen cells. Time, ten minutes.

Result.—Clot same at the positive pole as in Experiment IV., but action on lining membrane was much less than in that experiment. Gas escaped at negative needle. No clot at negative needle. Artery compressed only below, circulation arrested.

Experiment XI.—Renal artery of dog was cut, and blood allowed to flow into peritoneal cavity. As it flowed, negative and positive steel, non-insulated needles, connected with eighteen cells, were dipped into it. Action commenced at once. A dark clot formed about positive needle, and a light foam around negative. At the end of one minute, at the positive needle, a black clot had formed, a quarter of an inch in diameter, dense enough to be lifted out of the fluid on the point of the needle, and to sustain its own weight. At negative needle there was a spumous yellow mass, which could be lifted in part from the blood on the needle's point, but which had no consistence whatever.

Blood coagulates so quickly after it leaves the body that when we wish to determine the chemic action of the electric current on it, it is necessary to introduce the needles into the vessels of the living animal, or into the blood, just as it is flowing from the vessels.

With the assistance of Dr. J. H. Raymond, we made similar experiments on dogs and rabbits. The animals were etherized, cut open, and the needles (platinum) inserted into different arteries and veins. In some cases also the arteries were ruptured, and the needles were introduced into the pool of blood before it had time to coagulate.

The conclusions in regard to the electro-coagulability of the blood, to which we have been led by these repeated experiments on animals and on men, are these:

1. Both poles of the galvanic current cause a clot in blood, either running in an artery or vein, or freshly drawn, and stationary.

2. The positive clot is black, hard, and small; the negative clot is light, soft, and bulky.

3. These clots are the result of the electrolytic action of the current, with the evolution of oxygen and hydrogen, of acids and alkalies, and their subsequent combinations.

4. The largest clot and most satisfactory observation in an artery is caused when both poles are placed within the blood-vessel and near together. The reason of this is, that when the poles are near together in the blood, the resistance is very much less than when one of the poles is on the surface.

5. In order to produce a firm clot of sufficient size to obstruct a large artery, strong currents—from one hundred to two hundred milliamperes—are required, and quite protracted séances. The process of coagulation under the current is comparatively a slow one.

6. Electro-coagulation in a blood-vessel is aided by any compression that impedes the rapidity of the flow of the blood. The slower the current runs, the more rapid and firm the coagulation. Small and recent clots, especially those connected with the negative pole, may possibly be washed off. The practical bearings of these conclusions on the electric treatment of aneurisms will appear in the section on Electro-Surgery.

According to some late experiments,* the action of the galvanic current on the blood increases the amount of ozone. The oxygen in the

* "The Primary Action of the Galvanic Current," Mount Bleyer and Weill, Transactions of the American Electro-Therapeutic Association, 1893.

blood exists in two forms: First, that which is held in solution by the plasma; second, that which enters into combination with the constituent elements of the corpuscle or oxyhæmoglobin. This oxyhæmoglobin is given up as soon as the oxygen of the plasma has become exhausted and the pressure reduced, as in the capillaries. This interchange continues until the pressure of the oxygen in the lymph equals the oxygen in the plasma. The galvanic current facilitates this transfer. In the preliminary test the atmosphere was shown to be free from nitrous compounds by the Gries-Slosvay formula, and from ozone by the iodide of starch and tincture of guaiacol tests. Sixty grammes of blood were then taken from a rabbit and defibrinated. The serum showed ozone in small quantity, the clot in far greater amount. After galvanization the clot showed more vivid and longer reactions. This was due to the polarization of the neutral oxygen. This polarization of the oxygen seems to take place just as the gas touches the tissues, where the conditions are favorable to such action and where it closes circuit with electricity in the human frame. The interesting observation was made by analysis of the blood, that the ozone was much greater in the blood of an animal strongly under the influence of the galvanic current than in normal blood.

CHAPTER X.

ELECTRO-CONDUCTIVITY OF THE HUMAN BODY.

THE chief constituent in the human body is water, which is about three-fourths of its average weight.* The saline constituents which the water holds in solution vary in quantity and quality in the different tissues and the different parts and organs of the body.

The conductibility of the body, as a whole, may be best understood by regarding it as a mass of water and saline ingredients, with solid tissue interspersed. The degree of resistance to the current that different parts of the body offer will therefore depend on their structure. Those parts which, like the bones and epidermis, contain little water, will offer a much greater resistance, and be poorer conductors, than those parts which, like the muscles, nerves and tendons, and cartilages, contain a large percentage of water. Soft parts, like the stomach, intestines, and mucous membranes in general, offer comparatively little resistance, because they contain so large a percentage of saline solutions. Saline solutions conduct better than simple water, and warm saline solutions conduct better than those which are cold.

The human body, as a whole, conducts electricity fifteen to twenty times better than pure cold water, provided the skin is thoroughly moistened. It owes this superior conductibility to the warm saline solutions which it contains. According to recent experiments by Richardson, the blood is the best conducting material of the body.

Percentage of Water in the Tissues.—To ascertain the relative proportion of water in the different tissues of the body is a subject that has occupied a number of observers. The results of the different investigations do not agree mathematically, for the reason, partly, that individuals differ in the water-holding capacity of their tissues, as in all other respects.

The following table† gives at a glance the results of the different investigators:

* Pereira: "Food and Diet," Am. ed., p. 39.

† Ziemssen: "Die Electricität in der Medicin," vierte ganz umgearbeitete Auflage, Erste Hälfte, p. 18, 1872.

Percentage of Water in the Tissues of the Human Body.

	Adults.		New-born children.
Blood	80.5 (E. Bischoff)		85.0 (Bischoff)
Gray matter of the brain	85.0 (Lassaig)	77.2 (Ranke)	88.6 (Bischoff
White " " "	73.0 (Lassaig)		
Gray matter of spinal cord	71.0 (LèHérit)	70.8 (Ranke)	81.8 (Bischoff)
White " " "	65.0 (Von Bibra)		
Nerve matter	77.0 (Ranke)	39.68 (Von Bibra)	64.5 (Von Bibra)
Muscle	81.2–84.8 (Ranke)		87.8 (Bischoff)
Liver	76.1 (Von Bibra)		82.5 (Oidmann)
Elastic tissue	70.4 (Schultze)		
Fatty "	80.9 (Ranke)		
Connective tissue — cornea	75.8 (His)		
Connective tissue — skin			
Connective tissue — *lederhaut*	57.5 (Wienholt)	79.1 (Ranke)	
Bones—os parietal	14–16 (Friedleben)		18–29 (Friedleben)

An examination of the above table shows clearly these two facts:

1. The percentage of water in the different tissues of the human body, excepting the skin and bones, is almost uniform—ranging between 70 and 90. The percentage of water in the skin is almost two-thirds as great as in the brain, spinal cord, and nerves. In the bones the percentage of water is one-fifth that of the soft tissues.

2. There appears to be more water in the tissues of new-born children than in adults. The difference, however, is but trifling.

Investigations of a similar character have been made on the tissues of oxen, dogs, frogs, cats, hares, and rabbits; the results do not differ materially from those obtained on the tissues of human beings.

Compared with a number of metallic substances, the human body is an exceedingly poor conductor. Thus it has been estimated that copper is several thousand million times a better conductor than the human body.

Dr. C. B. Radcliffe made three experiments, in which he measured the resistance of nerve, tendon, and muscle, as nearly of the same shape and size as possible. The pieces were taken from the sciatic nerve, the tendo-Achillis, and the adductor longus of a recently killed rabbit. He found the mean resistance of one inch of the sciatic nerve to be 40,000 units—that is, about eight times the resistance of the Atlantic cable; of the tendon, 38,000 units; and of the muscles, 12,000 units.*

Bones and Skin Poor Conductors.—It should never be forgotten that the

* "Dynamics of Nerve and Muscle," p. 19.

epidermis, in a dry state, is a poor conductor. In practice this resistance of the epidermis is overcome by thoroughly moistening it. The hair and nails are also poor conductors. In making applications to the top of the head it is necessary to thoroughly moisten the hair. The bones contain less water than the soft parts, and are consequently poorer conductors. Soft parts which are thus enclosed in a bony covering are less powerfully affected than soft parts which are not so enclosed.

The Current Tends to Take the Shortest Way between the Electrodes.—The electric current always takes the shortest and most direct course from one pole to the other, provided the media intervening between the electrodes is of a uniform conductibility. When, therefore, the positive electrode is applied to one part of the body, and the negative to the other, the current would diffuse itself uniformly between the poles, provided the structures of the body between them were uniform. But, as has been seen, the different parts of the body vary widely in regard to their conductibility,—those which contain a large quantity of saline solutions being good conductors, and, *vice versâ*, those which contain a small quantity being poor conductors,—the difference of conductibility between bone and muscle being nearly twenty to one.

The current does not affect all parts alike. The extent to which any part is directly reached, when the current is applied over the surface, will depend both on its structure and its situation.

Soft parts, which contain a large amount of water, like the brain, spinal cord, and abdominal viscera, are good conductors, and unless their situation is unfavorable, they are directly and powerfully affected by the current, when applied to the surface by means of moist conductors. On the other hand, bone, which contains a much less percentage of water than the muscles and soft parts, is comparatively a poor conductor. Accordingly, soft parts which are partially or entirely enclosed by bone are much less readily affected by external applications than would be the case if they were exposed.

Another legitimate inference from the accepted theories of the nature of electricity, and from what we know of the relative conductivity of the different tissues of the body is, that when electrodes are placed on the surface of the body the current moves between them in a kind of undulative or wave-like manner, extending on both sides of the median line between them for a considerable distance.

That these theories, in regard to the electro-conductivity of the body, are sound, is proved in three ways:

1. By experiment on the living subject.

2. By direct experiment with the galvanoscopic frog and reflecting galvanometer on the dead subject.

3. By the evidence of pathologic cases.

That the tendency of electricity is to take the shortest road between the electrodes is proved by the following experiment: The two forearms are crossed so that they touch each other a little distance above the wrist. Placing now one electrode on the outer surface of each arm, and letting the galvanic current run, a feeling of heat and pricking is felt, not only beneath the electrodes, but also, to a less degree, at the polar surfaces of the forearms where they touch each other. On removing the electrodes it is observed that not only the spots beneath the electrodes, but also the spots where the arms touched, have become reddened.

This shows that a portion of the current takes the shortest way from one electrode to the other, although that road lies through two layers of epidermis, which is a very bad conductor.

A portion of the current, in this experiment, goes up the arm, across the body, and down the other arm.

In order to ascertain what proportion of the current took the route across the arms, Ziemssen* made the following experiment: Putting one forearm over the other, as in Erb's experiment, he placed between them two plates of zinc, connected with a delicate reflecting galvanometer. The result of the experiment, when 20 elements were directed across the arms, was a deflection of the needle 36.3°. The same arrangement made on the dead body gave, with 10 elements, a deflection of 8.5°; with 15 elements, a deflection of 19.7°; with 20 elements, 28.2°. On separating the forearms, so that the whole current must run around through the arms and body, he found that with 10 elements there was a deflection of 15.9°; with 15 elements, a deflection of 31.7°; with 20 elements, a deflection of 48.5°. The conclusion was that in each experiment one-half of the current went across through the forearms, and the other half up and down the arms and through the body.

Evidence of Pathologic Cases.—When the spinal cord is in a condition of health, a powerful current may be applied down the back without discomfort; but in cases of myelitis, spinal congestion, and other morbid states, very marked and peculiar symptoms are sometimes observed. We have seen a case of myelitis when even a very mild faradic current over the spine, near the supposed seat of the disease, caused severe pain in the right leg that continued for several hours. Such a phenomenon is never observed in health. The fact that it does occur, especially when the electrodes are not placed near any prominent nerves, shows very clearly that the current affects the spinal cord in a more direct way than by mere reflex action.

The sensations of the patient, and the results of treatment, also show that the stomach, liver, spleen, intestines, and the genital organs in both sexes, are traversed by the current in external applications of either current.

Experiments on Dead Subject with a Frog Preparation.—Erb opened the

* Op. cit., p. 22.

skull of a dead body, took out the brain, and covered the outside of the skull with pieces of muscle about three-quarters of an inch thick. Over the muscle pieces of skin were placed, and over the skin the electrodes. The skull was then filled with the brain, in such a way as to avoid any direct connection with the muscle. The skull was thoroughly dried, and a prepared frog placed on the cerebral matter. A very gentle current was then let on, and both on opening and closing the frog contracted energetically, showing that a portion of the electricity at least passed through the brain. Branch currents may also have gone around through the layer of muscular tissue; but the important point, that some of the electricity took the short way direct through the skull and brain, was in this experiment conclusively shown.

The same experiment with the faradic current showed the same result.

Similar experiments on the spinal cord showed that the current penetrated the vertebræ as readily as through the skull.

Hare,* on the other hand, comes to a different conclusion. The fact being admitted that electricity always flows in the direction of least resistance, the problem to be solved in his experiment was whether the roundabout route by the scalp, or the more direct one through the head from side to side, offered the more resistance. The positive pole of the battery was applied to the occiput and the negative to the forehead of a large dog, and a milliamperemeter placed in the circuit now registered $5\frac{3}{4}$ milliamperes. The dog was then trephined. The meter still in the circuit, a needle, thoroughly insulated except at its tip, was inserted into the brain substance. The meter now registered $3\frac{3}{4}$ milliamperes. In other words, the resistance to the current, when one of the poles was bare metal and in the middle of the brain, was greater when the current had to pass through the wet sponge, bone membranes, and scalp, than when the current had to pass from pole to pole by the scalp. "If this is the case," says the author, "how much greater must the resistance be when the current has to pass through both sides of the skull instead of only one side, as in my experiment!" Deve's † experiments, however, lead him to the following quite opposite conclusions: 1. The current passes through scalp, bone, and encephalon. 2. It is stronger in the scalp, and grows weaker by diffusion, the more rapidly when electrodes are removed furthest from the biparietal line. 3. It spreads evenly through the entire encephalic mass.

Actual Experiment with a Reflecting Galvanometer.—The evidences already given are sufficient, with corroboration, to establish the fact that the electricity, when applied to the surface of the body, goes through the tissues lying between the electrodes, and that all the internal organs may be thus acted on by the current. The mathematic demonstrations of this

* Therapeutic Gazette, December 15th, 1893.

† Times and Register, January 27th, 1894.

fact that have been recently made by Burchardt, and after him by Ziemssen, are, however, none the less interesting. Ziemssen's method of investigation was to insert two platinum needles insulated to their points into the organ to be experimented on, as the brain, spinal cord, sympathetic, lungs, liver, etc., and connect them with a delicate Wiedmann's reflecting galvanometer, while the electrodes of a galvanic battery of from 1 to 50 elements were applied externally, in such a way that the current, in passing from one to the other, must pass through the place where the points of the needles were inserted. These experiments were performed on the dead subject, and on animals, living and dead. Unpolarized needles were used. The body, or part to be examined, was isolated on wood or glass. By these means he easily demonstrated these two facts:

1. That all the internal parts and organs of the body can be traversed by derived currents when the electrodes connected with a galvanic battery are properly placed on the skin.

When the electrodes are placed on the head, derived currents pass through the brain. When the electrodes are placed on the spine, derived currents pass through the cord. In the same way it was demonstrated that the sympathetic, heart, lungs, liver, spleen, intestines, and bladder were traversed by derived currents when the electrodes were applied respectively to the neck, thorax, and abdomen. Similarly also the nerve-plexuses and great veins were shown to be traversed by currents when external applications were made.

2. The derived currents were usually most powerful, that is, the greatest quantity of electricity passed in a direct line, between the electrodes.

When the ends of the unpolarized needles were removed from one another, near the central line, the needles showed less and less deflection, proving that the derived currents were weaker. To this general law there are, however, exceptions. The current which contains a very large percentage of water conducts electricity better than other neighboring parts, even when out of the axis of the curve.

3. The derived currents can be sent through the internal parts in any direction, and increase in strength with increase in the strength of the principal current.

When the principal current is reversed, the derived currents will be reversed also. In one experiment, on the dead body of a young man, the electrodes of the principal current were placed behind the ears. Two holes were made in the parietal bones, in the track between the electrodes, and two other holes were made, about 6 cm. farther forward, and about 8 cm. from each other. In the holes made through the bones into the brain were placed the unpolarized needles connected with the reflecting galvanometer. Two needles were also in the tubercula quadrigemina.

In the above observation, which may be regarded as a crucial and convincing one, these three points are distinctly proved:

First, That the current passes from one electrode to the other through bone and brain.

Second, That most of the derived currents take the direct route in the axis between the electrodes, and that the strength of the derived currents, the conductivity of the parts being the same, diminishes in proportion to their distance from the axis.

Third, That the tubercula quadrigemina, by virtue of their fluid structure, conduct electricity better than the after-parts of the brain.

Fourth, That the strength of the currents sent through the body is proportioned with considerable exactness to the strength of the current employed in the application.

The laws of conductivity of the body, as here demonstrated in the brain, have also been similarly demonstrated in the spinal cord and in all the organs of the thorax and abdomen.

The grand conclusion from all these experiments, and from clinical experience, is that the electro-conductivity of the human body is to be explained, mainly, by the ordinary physical laws of electro-conduction, and only to a very limited extent by physiology.

Physiology and pathology may come in to modify, to a slight extent, the conductivity of the body; for, as we have seen, individuals differ in their conductivity. Increase in the quantity of blood or salts in the body increases the conductivity, and diminution of blood or of the salts, as takes place in some diseases, diminishes the conductivity. But all these varying factors have caused only a very slight perturbation of the physical laws of electro-conductivity.

There is some difference in the conductivity of the living and dead body, but this difference can mostly be explained by physical principles. It may well be questioned whether the principle of life, whatever that may be, exerts any very important influence on electro-conductivity. Burchardt found that when more saline solutions were injected into the dead body the electro-conductivity was increased. This is just what we should expect on physical principles, because warm saline solutions are good conductors of electricity in the body or out of it.

According to Ranke, living muscle conducts much worse than dead muscle, the proportion being as 100 to 56. Living muscle conducts 115,000,000 times, and dead muscle 64,400,000 times worse than copper. Dead muscle conducts better than living, on account of the decomposition and chemic changes that take place after death, and especially on account of the accumulation of lactic acid.

Electro-Conductivity Modified by Age and Temperament.—Young people offer greater resistance than old people, for the probable reason that the tissues of the old contain more of the salts than those of the young. The hands of those who labor with muscle, and whose epidermis is thereby thickened, offer greater resistance than the hands of those who live by brain alone. The right hand, being more used than the left, has a thicker epidermis, and therefore presents a greater resistance.

Different individuals of the same age and condition differ in their conductivity in a manner that cannot be fully explained. When "shocks" of a battery, or faradic machine, or Leyden jar are sent through a number of persons in a row, some will feel it slightly, others strongly, and perhaps one or more may be almost if not quite prostrated. This fact may explain some of the freaks of lightning, for it has long been known that when a number of persons are standing near together some may be struck down and others unharmed. Some Indians and negroes, it is said, can take hold of the electric eel without receiving shocks.

The same individual may conduct differently at different times. As the body is perpetually changing, as it varies in its intimate constitution, not only from year to year, but from day to day, and from moment to moment, it is easy to understand why it should vary in its susceptibility to electricity, just as it varies in its susceptibility to the articles of ordinary food, to stimulants and narcotics, and to internal medication.

CHAPTER XI.

THE EFFECT OF ELECTRICITY ON NUTRITION.

It is not a little surprising that electricity should have been used as a therapeutic agent for more than a century before it began to be recognized among scientific men as a powerful means of aiding nutrition. When, after a series of preliminary experiments, we ascertained that electrization was a tonic of most remarkable efficacy; that its permanent tonic effects were, indeed, far more valuable than its primary stimulating effects, the statement was received by many, and especially by those accustomed to and familiar with other electro-physiologic and electro-therapeutic researches, with incredulity and surprise.

The attention of observers has been so exclusively directed to the primary stimulating effects of electricity that they have neglected to pursue the subject further, and to study its permanent effects on nutrition.

The effects of the passage of electricity through the body are of a fourfold character:

1. Mechanic.
2. Physical.
3. Chemic.
4. Physiologic.

Inasmuch as the effect of electricity on nutrition is a resultant of all these four orders of effects, it is necessary to speak of each in some detail.

The mechanic, physical, and chemic effects of electricity on the body are similar in character to the same effects of electricity on any substance whatever; the physiologic effects are those which take place in virtue of the vital properties of the tissues. The mechanic effects of electricity on the body are most markedly appreciated under the faradic current. The reason is clear from the nature of the faradic current. It is a current of alternation, of to-and-fro motion, of constant closing and breaking. When it passes through the body, even when it produces no muscular contraction, it acts very much in the same way as gentle tapping, or pounding, or rubbing on the tissues; and this gives passive exercises to all the deeper lying as well as the superficial tissues. We may believe that the molecules of the tissues are agitated by the passage of the current, as the particles of a bar of iron are moved by the influence of magnetization, or as bodies are expanded by heat. The numerous branch currents going to and fro act as so many shuttlecocks, keeping every atom in incessant disturbance. That the simple process of tapping on the surface of the body, by means of the vibrations that it excites, has a positively beneficial effect in certain chronic affections, has long been recognized. It is reasonable to suppose that this beneficial effect is in part due to the increase of endosmotic action.

Physical Effects.—The physical effects of the passage of electricity through the body are heat, and the modification of endosmose and exosmose, and the transference of substances from one pole to the other.

The heat excited in the body by the simple passage of a weak current that causes no muscular contraction, is small; but there is little question that heat is thus excited, although it is difficult or impossible to measure it by the thermometer. The main arguments in favor of this belief are (1), that all conductors of electricity become heated more or less in proportion to their resistance—the body offers great resistance, and more or less of the electric force must be converted into heat; and (2), powerful currents, either galvanic or faradic, even when not used so as to excite muscular contractions, cause increase of heat in the track of its passage, so marked as to be easily detected by the touch. No thermometer is necessary to show that in electrolytic operations, where strong currents are used, the tissues near the needles, and between them, become intensely heated, so that to rest the finger on them almost causes pain. This fact we have demonstrated over and over again in various parts of the body. It is equally clear that the faradic current, even when not very powerful, raises the temperature of the parts through which it passes. The sensation of the patient and palpation by the operator demonstrate this beyond doubt. Cold extremities are warmed sensibly and quite rapidly by faradization or galvanization, even when no sensible muscular contractions are produced by the current. Schiff declares, as a result of his observations, that a nerve is warmed by an almost momentary passage of the current.

A second important physical effect of the passage of an electric current through the body is the transference of substances from one pole to the other. This physical effect of the current has long been recognized. In the electric light, for example, the particles of carbon go from the positive to the negative pole, and to so marked a degree that the positive carbon is quite rapidly worn away. A very remarkable illustration of this transference of matter in the track of electricity sometimes occurs in lightning stroke. Trustworthy cases are reported of individuals who have been found struck dead by lightning, and bearing on their bodies distinct images or impressions of some object, as a tree or house, near which they stood when they fell.

In 1864, at Nibelle, in France, three men who were gathering pears were struck by lightning. One was killed at once. The others were thrown to the ground unconscious, and one of these, when taken home, was found to have on his breast a "distinct daguerrotype of the tree."

In 1860 a woman of Sisonne, in France, who was struck by lightning, carried on her back a complete image of a tree—trunk, branches, and leaves—that was near the place where she fell. A similar case is recorded by Franklin.*

The explanation of all these cases is the same. The particles of the tree, reduced to great fineness by the electricity, are mechanically transported and burned in the skin. The process is therefore not chemic, but mechanic and thermic.

Bodies have been literally tattooed in this way. Transference of substances is a part and result of the electrolysis in organic substances already described, and also of the electrolysis of organic bodies to be hereafter described.

The electric currents also exercise a positive and very interesting influence over endosmose. By the passage of a galvanic current the endosmotic phenomena may be both stimulated or reversed. This is shown in the following experiment of Dutrochet: A tube containing gum-water is closed at one of its ends by animal membrane and dipped in a vessel containing common water. By the ordinary operation of the laws of endosmosis the gum-water rises in the tube on account of the entrance of some of the ordinary water through the membrane into the tube. But if the positive pole of a galvanic battery be placed in the common water, and the negative pole in the gum-water, the endosmotic action is stimulated to such a marked degree that the level of the gum-water rises with much greater rapidity; if we reverse the pole the level of the gum-water in the tube sinks instead of rises. The faradic current from the secondary coil produces no such effect. The current from the inner coil—the extra current so called—produces these effects to a less degree. It is pretty clear, therefore, that these phenomena depend on the chemic and not on the mechanic power of the current.

Electric Endosmosis is Influenced by Strength of Current and Resistance of Circuit.—It is found that the quantity which rises is in exact proportion to the strength of the current, and to the extent of the porous surface. It has been found that the greater the resistance of the liquid to electrolysis, the more it yields to this endosmotic action.

The above phenomena have been demonstrated at different times, and by a variety of observers.

Besides the physical effects above described, there may be many others that we cannot at present recognize or appreciate, but which may be revealed by the spectroscope and other means of refined research.

* "Death by Lightning," by M. Dr. Fedet (Clermont Ferrand), Gazette des Hôpitaux, June 8th–10th, 1872, translated in The Clinic, July 6th, 1872.

After-Physical Effects of the Currents.—It has been observed that platinum wires are contracted by the passage of electric currents through them, and that copper wires that are used for conducting electricity become brittle thereby. The differential action of the faradic and galvanic currents in this respect is quite interesting, for, according to Ruhmkorff, the copper wires that conduct faradic currents break more speedily and more frequently than those which conduct galvanic currents.

This physical fact is very suggestive of what may be facts in physiology and pathology. We have already seen that magnetization has physical effects of a most decided character. We have seen that it causes sounds to proceed from the body magnetized; that the body magnetized also becomes elongated; and that this elongation is probably due to the fact that the particles arrange themselves, during magnetization, lengthwise in the direction of the bar. It is not improbable that the human body in health and in disease may also be changed by the action of the currents in a manner that we do not yet comprehend, and that such physical or physiologic changes may account for some of the therapeutic effects of electrization. This probability applies especially to the after-effects of electric treatment, effects that are noticed not while the applications are being made, or during the course of the treatment, but weeks and months after the treatment is discontinued. On this subject we shall speak in more detail in the section on Electro-Therapeutics.

Chemic Effects.—The chemic effects of the current are mainly of an electrolytic character. They consist of an electro-chemic composition of the fluids of which the body is composed. The general laws and phenom ena of electrolysis in its relation to inorganic substances have already been set forth in the chapter on that subject in Electro-Physics. It remains for us here to speak of electrolysis, in its relation to organic life. At the outset we may remark that there is no evidence that organization, as such, seriously modifies electro-chemic decomposition. The fluids of the body decompose under the influence of the current, just as the same combination of fluids with tissue would decompose if not endowed with life. If the results of the electrolysis of the dead body are different from the results of the electrolysis of the living body, it is because of the chemic changes that take place in the body after life has departed.

The human body is composed of fourteen different chemic substances, many of which are singly capable of decomposing under the current, and in their various combinations are capable of many decompositions and recompositions, with secondary results that cannot well be estimated.

The general facts of the electrolysis of inorganic substances, the appearance of oxygen and acids at the positive pole, and hydrogen and alkalies at the negative pole, apply also to the electrolysis of the living body. The great law arrived at by Faraday, that in electrolysis substances are decomposed in equivalent proportions (see Electro-Physics), also finds no exception or interference in organic structures.

Some of the Phenomena of Electrolysis of Living and Dead Tissues.—In order to determine the electrolytic effect of the current on organic substances we have made a wide variety of experiments on both living and dead tissues, fluid and solid, in a normal as well as pathologic condition, on animals and men. We have tried the galvanic current on the voluntary and involuntary muscles; on the mucous and serous membranes; on brain, spinal, and nerve matter; on the lungs, the heart, the liver, spleen, stomach, intestines, bladder, uterus; on the saliva and the urine; on the cartilage and on bones. The general conclusions at which we have arrived from these experiments are these:

1. All these animal tissues, living or dead, decompose, so far as can be seen, like inorganic substances, and by uniform laws.

2. The fact most patent to superficial observation is that the rapidity of the electrolysis depends more on the amount of fluid in the tissues than on all other factors combined.

3. The great difference in the effects of electrolysis on organic and inorganic substances is seen after the current has ceased to act. In the electrolysis of most inorganic substances—such for example as iodide of potassium, acetate of lead, chloride of sodium, and so forth—the effects cease as socn as the current ceases; the substances remain in the condition that the current left them. The electrolysis of organic substances starts a process that continues long after the current ceases to flow.

Electrolysis of the White of an Egg.—When the white of an egg is electrolyzed by copper needles or wire, white flakes rapidly form around the needle connected with the negative pole, covering the needle as cotton covers a bobbin of a loom. This white covering soon becomes detached from the needle, if the current is tolerably strong, and floats on the surface of the albumen, and then another similar envelope is formed over the needle. In a little time the surface of the albumen becomes covered with white, slight masses, resembling what are known on our tables as "floating islands." These formations are not coagula, as might be supposed, but are simply composed of hydrogen gas enveloped by very thin layers of albumen, into which it is mechanically driven by the electrolytic action, after the analogy of soap-bubbles and the froth of a beaten egg, where the distention is caused by common air enveloped by water and albumen.

Besides these changes the albumen becomes discolored, and reddish-yellow streaks are found at both poles. This discoloration is due partly to the action of the oxygen or the albumen on the copper of the electrodes.

Although, as has been said, platinum wires at the point of insertion into the substance are best for these experiments, since they are not acted on, and exhibit the changes in their purity, yet a common sewing or darning needle, or copper wire, will answer; but it should be borne in mind that the action of the substances on these will complicate the observation, and that they will in a short time become destroyed by oxidation.

Electrolysis of Fresh Milk.—When fresh cow's milk is electrolyzed with platinum needles an odor of chlorine is distinctly perceived, due to decomposition of the chloride of sodium, and little islands of foam appear on the surface. This foam, on being broken up, gives forth an odor of chlorine, and disappears, showing that it is not coagulated albumen, but simply chlorine gas and albuminous envelopes.

Electrolysis of the Aqueous and Vitreous Humors of the Eye.—When platinum needles connected with a galvanic current are inserted into the aqueous and vitreous humors of the eye of a dead or dying rabbit, rapid electrolysis takes place at both poles, with evolution of gases in albuminous envelopes. A cloud resembling cataract is speedily formed over the pupil, and in a few moments, if the current be of medium strength, the covering of the eye will be ruptured, with a violent escape of albumen-enveloped gases. This process, which we have frequently studied in the eyes of rabbits and dogs, is similar to that which takes place in the electrolysis of hydrocele and of certain cystic tumors.

Electrolysis of Beef.—It is possible to gain a measurably correct idea of what changes take place during and after electrolysis of the living body, in health or disease, by studying the phenomena that appear during electrolysis of dead tissue. If a piece of beefsteak, for example, be subjected to the action of the galvanic current by needles connected with the positive and negative poles, a process somewhat resembling frying can be distinctly seen and heard and felt; more specifically, bubbles of hydrogen appear at the negative pole, and a kind of hissing sound is heard, even when the ear is at some little distance, and a positive sensation of heat is felt when the finger is pressed over the part that is being electrolyzed. Under the microscope this process can be more closely studied. Chemic examination shows that oxygen, acids, and albumen go to the positive pole, while hydrogen, alkalies, and coloring matter go to the negative, and the action at the negative pole is much greater than at the positive. Under this process the beef becomes gradually dried and changed in color, owing to the disappearance of the watery constituents and the other electrolytic action; and, in proportion as the beef grows drier and the fibres begin to lose their adherence and fall apart, the electrolytic process becomes less and less active, because there is less fluid on which to act.

For some hours after the needles are removed, the process of drying and disintegration and decoloration goes on, until the portion that lies between and near the poles shrivels, contracts, and crumbles, until it resembles the burnt corners of a piece of roast beef.

Electrolysis of Fruits and Vegetables.—We have experimented on a variety of fruits and vegetables—as oranges, lemons, apples, pears, peaches, potatoes, turnips, etc. The effects of the electrolytic action, as they appear to the eye and the ear, though consistent with the great general laws of electrolysis of inorganic substances, yet are more or less modified by the varieties of structure. When a sound apple is electrolyzed, the part around the negative needle changes in color and looks as though it had been bruised and was beginning to decay, and the needle soon becomes loosened and will easily fall out. The process of drying and decoloration goes on after the operation is discontinued. In fruits and vegetables the electrolytic changes that take place are largely due to the electrolyzation of water, which is aided by the acids that they contain.

When muscles have been separated from the body and submitted for several days to the action of a strong galvanic current, there have been found at the positive pole sulphuric, phosphoric, hydrochloric, and azotic acids, and at the negative pole alkalies—as soda, potassa, and ammonia.

Legros and Onimus have shown that when an alkali, as carbonate of soda, is placed at the positive pole in electrolysis of the human body, and an acid—as tartaric acid—at the negative pole, the usual eschars have not been formed. This would seem to indicate that the cauterization in electrolysis is due in part to the acids and alkalies that result from the decomposition.

This cauterizing action is not solely due to the acids and alkalies, for, when other acids and alkalies are applied to the body, eschars of the same degree are not obtained. The current penetrates and pervades the tissues and induces various changes beyond and beneath the eschar, which changes continue long after the current is broken.

The phenomena above described all occur under the galvanic current, and with needles as electrodes.

The current from the primary coil of the faradic machines has some electrolytic power, and even the current from the secondary and tertiary coils is not without some chemic effect. It is not necessary to use needles or pointed electrodes of any kind in order to produce electrolysis; but with a sufficient strength of current the phenomena may be produced by large, flat, metallic surfaces. There is more or less electrolysis in all the ordinary applications of electricity to the body, whether made with metals or sponges, small or large.

Physiologic Effects.—The physiologic effects of electricity, properly so called, are those which take place by virtue of the vital properties of the body. The other effects above described—mechanic, physical, and chemic—are not peculiar to living bodies; they are observed on the dead as well as the living, on inorganic as well as organic substances, although they are, as we have seen, more or less modified by vitality. But the physiologic effects of which we are here to speak are peculiar to organization; they cease when life ceases, for they are mainly the modification of the vital processes by electricity.

There are in general four ways in which electricity applied to the tissues modifies their physiologic functions:

1. It may increase them.
2. It may diminish them.
3. It may arrest them.
4. It may modify their quality.

Some of the more important illustrations of their effects have been already discussed.

We have seen that electricity, according to the kind that is employed, and according to the method and strength and length of the application, causes various phenomena on the skin, contracts voluntary and involuntary muscles when applied either to the muscles themselves or to the nerves that supply them, and increases the process of oxidation, and raises the temperature, excites the nerves of common and special sense so as to cause pain, flashes before the eyes, noises in the ears, and a peculiar taste and odor. When applied to the pneumogastric it increases, diminishes, or arrests the action of the heart.

It remains here to speak of the following physiologic effects of electricity:

1. On the circulation.
2. On secretion and excretion.
3. On absorption.

The effect of electricity on the circulation is somewhat complex. It includes the effect on the heart and on the unstriped muscular fibres of the arteries, as well as on the central and peripheral nervous system in general, since the flow of blood in the arteries, veins, and capillaries is influenced by the quality and quantity of innervation that they receive. We have to speak merely of the direct effect of electricity on the capillary circulation. It has been shown already that electrization of the cervical sympathetic may have the directly opposite effect of contracting or dilating the vessels of the retina. That the same opposite effects may follow electrization of any part or organ, depending on the temperament of the patient, the quality of current, and the length and strength of the application, is also demonstrable. One effect is constant under all conditions, and that is, that the circulation is modified in one or the other, or in both ways. The average ultimate effect is to increase the flow of blood, raise the temperature, and dilate the veins. Dilatation of the veins, after prolonged electrization, is a phenomenon that can be demonstrated with ease on any part of the body where the veins are prominent. The back of the hand is the best place to study this phenomenon, and faradization illustrates it most distinctly.

This enlargement of the veins is accompanied by a rise in temperature, and especially if the muscles have been brought into vigorous contraction, that is not only indicated by the thermometer, but is appreciated by the subject. Under general faradization the hands and feet become warmer during the sitting, and may remain warmer for hours. Central galvanization, or galvanization of the cervical sympathetic, also warms the periphery.

On Secretion and Excretion.—The secreting power of the secreting organs of the body is very markedly influenced by electrization.* The usual effect is to increase their activity; but when very mild currents are used, such effect is not always observed, and it is probable, from our experiments, that very strong currents may produce a reverse effect.

On the lachrymal glands the action of the current is not so easily shown, because strong currents are not well borne on the face or head, and the glands themselves are not directly accessible. It is difficult to decide whether the flow of tears that accompanies strong electrization of the face is the result of the mechanic irritation or the physiologic action of the current on the lachrymal glands or the nerves that supply them.

The secretion in mucous membranes is quickly increased by electrization, as can be demonstrated most easily on the Schneiderian membrane by means of metallic electrodes introduced in the nasal passages. This fact becomes of practical importance in the treatment of the so-called "dry catarrh," and also in exhausting diseases associated with dryness of the mucous membranes.

On the salivary secretion the effect of the current is very easy of demonstration. That application of the current, both galvanic and faradic, can increase the secretion of the salivary glands, is very easily demonstrated. We have shown this at various times during the past five years, galvanizing or faradizing the tragus of the ear, with either pole, or against the membrana tympani. This effect is due to the excitation of the chorda tympani nerve, some of the fibres of which go to the submaxillary ganglia. This increase of saliva is sometimes so great that, while the current is flowing, continual swallowing is necessary.

In sensitive persons the same effect follows, by reflex action, electrization in almost any part of the neck or face. In certain pathologic cases, as Addison's disease, we have found the annoying dryness of the mouth greatly relieved by electrization, and in pathologic cases of the severe character, as in diabetes, when the salivary secretion may be greatly diminished, we have found central galvanization to increase the secretion quite rapidly.

On the biliary secretion the action of the current is less easy of mathematic demonstration. The results of external electrization in pathologic cases seem to prove that the quantity of the bile may be increased.

* "Ueber die Verwendung des galvaneschen Stromes zur Untersuchung der Sèkrete und Exkrete." Winkler (F.) und J. Fischer, Centralbl. f. klin. Med., Leipzig, 1893, 1–7.

Whether this increase is due to the action of the current on the substance of the liver, or the nerves that supply it, we are not able to state.

The secretion of gastric juice, and of the intestinal fluid, is in all probability increased by external electrization. Analogy would show these fluids ought to be secreted in greater abundance under the influence of the current, and the results of treatment in pathologic cases give this probability something of the force of certainty. Appetite is sharpened, digestion is quickened, and constipation relieved, both by local and by general electric treatment, so rapidly and so decidedly as to make it pretty evident that the gastric and intestinal fluids are made to secrete more liberally by the action of the current on the nerves that supply these organs than on the tissues of the organs themselves.

An excellent means of studying the variations in the nutrition is found in the elimination of the urine. This is believed to be a result of oxidation processes that may take place either in the kidneys or in the tissues, or in both.

Legros and Onimus have studied the effects of electrization of the spine on the elimination of urine.

Their conclusions, derived from more than 250 analyses, made on the urine of rabbits and of themselves, are these:

1. Interrupted currents diminish the quantity of urine and of azote.

2. Centrifugal galvanic currents increase the quantity of the urine and diminish that of the urea.

3. That continuous centripetal currents increase the quantity of urea without increasing the quantity of urine.

On the urinary secretion the effect of electrization can be demonstrated in pathologic cases without difficulty. In cases of diabetes insipidus and mellitus, local and general treatment may cause great diminution in the discharge, while in dropsy and in rheumatism we have known the kidneys to be stimulated as much as by powerful diuretics.

On the average man in health there is considerable difficulty in estimating a moderate increase of the urinary secretion under electrization, for the sufficiently apparent reason that the quantity of urine varies with so many conditions of food, drink, and exercise, and so forth. Unless the effect of electrization on the kidneys were immediate and decided, it would be difficult to differentiate between its effects and the effects of the other important and varying factors.

The influence of the general application of electricity, whether by the galvanic, faradic, or static forms, on the excretion of both urea and uric acid are most interesting and important. Our experiments have shown that in a number of pathologic cases, while treatment decreased the uric acid, it greatly increased the excretion of urea.

On the menstrual secretion electricity acts with remarkable power. Both currents, applied externally and internally, centrally or generally, in physiologic as well as pathologic cases, affect the quantity of menstrual secretion rapidly, and sometimes permanently. The effects are sometimes immediate, taking place during or directly after the application. The number of days that the menses appear are sometimes increased, and entire suppression is slowly or speedily cured.

In pathologic cases, where there is an excess of menstrual flow, electrization corrects and diminishes it. These apparent and interesting effects of electricity on the menstrual secretion may take place through the direct action of the current on the ovaries and the uterus, or indirectly through the brain, sympathetic, and spinal cord, and the nerves that supply the pelvic organs. They may take place through reflex action from electrization of the feet or hands, or other and distant parts of the body. Franklinic electricity also produces these effects.

The whole subject is of immense practical importance, as will be seen in the chapter devoted to Diseases of Women.

On the lacteal secretion electricity, especially the faradic current, acts with decided though varying power. It has never been known to diminish it, while it sometimes increases it, and it may restore it after it has been temporarily suppressed. This physiologic fact has a practical significance that will appear in the chapter devoted to Midwifery.

Similarly also the secretion of the spermatic fluid is increased by galvanization or faradization. A mathematic test of the power of electrization to increase the secretion of the testicles cannot, for obvious reasons, be obtained; but the statements of individuals on whom the experiment was tried seem to establish this point. The applications may be made not only through the testicles, but through the perineum and over the spine. The results are not invariable, but are obtained in a sufficient number of cases to make it fair to regard such effect as a law of electro-physiology.

The secretion of the sweat glands is also increased by powerful galvanization of the central nervous system, and especially of the cervical spine and sympathetic. In very susceptible patients either galvanization or faradization of the head, neck, or spine, and strong electrization of almost any part of the body, will cause sensible perspiration. We have seen individuals whom a few minutes of general faradization with feeble currents brought out large drops of sweat on the forehead, and made the hands as moist as though they had been dipped in water.

On Absorption.—The action of electricity on the absorbents is best studied in pathologic cases, such as hypertrophies, effusions, and morbid growths.

In thickening of the skin that appears in some cutaneous affections, in corneal opacities, in enlarged joints, in pleuritic effusions, in hydrocele, in dropsy of various parts, in passive œdema, and in enlarged glands, in tumors of nearly every variety, can be demonstrated the power of electricity to produce absorption. Reasoning backward from pathology to physiology, we justly infer that the same effect takes place, more or less, in all applications of electricity to the body, but that the degree of it is modified by the condition of the part to which the application is made. The effect on secretion is apparent at once to the eye or the sensation; the effect of absorption is apparent only to the eye, and then only when there is a visible excess of fluid or solid in the part to which the application is made. This part of our subject will be practically illustrated in various chapters both in Medical and Surgical Electricity.

Effects of Electricity Produced by Reflex as well as by Direct Action.—The reflex effects of electricity seem not to have been fully recognized by electro-therapeutists. There is considerable difficulty in ascertaining the precise reflex effects of electricity on animals. The effects as they show themselves on man are largely sensory, not motor; the stimulation of the circulation of absorption and of secretion that might and probably does take place, reflexly as well as directly, is too minute to be readily observed. We are justified in believing that electricity acts in absorption, secretion, and exertion by reflex as well as by direct action, from the fact that in irritable constitutions sensory effects on the sensation and on circulation, of a marked character, are produced by electric irritation. Thus, for example, when the hands or the feet are traversed by strong currents, either continuously or in sudden shocks, pain or disagreeable sensations may be felt in the hands and feet, of the opposite side, or in the back, or stomach, or side. These reflex effects are not constant, and when we look for them we may not find them. They can be best studied in persons who are susceptible to electricity, and whose spinal cords are weak and irritable. In some pathologic cases also, such as chronic myelitis of the anterior column (anterior spinal sclerosis), the reflex action of electricity is illustrated with great distinctness. Localized faradization, or galvanization of the lower limbs, may be felt not only in the part traversed by the current, but in the arms, in the opposite limb, in the back, and stomach to such a degree as to cause pain.

Strong currents acting on irritable constitutions may sometimes by reflex action shock the whole system, provided the application be localized in certain localities. Thus in a case of very obstinate constipation that we once treated by internal galvanization of the rectum, a current of not very great strength, suddenly interrupted, was disagreeably felt in the head, left hand, and feet. Very frequently, indeed, in experimenting on ourselves or other individuals, or on animals, and in treating patients, we have received shocks through the hands or arms that seemed to be felt in all parts of the body. In some instances the pain and disagreeable sensations thus caused by the reflex action of the current last for several minutes or hours.

On the circulation the reflex effects of electrization are demonstrable by delicate apparatus for testing temperature. It has been shown by experiments that electrization of one hand affects the circulation in the hand of the other side, so as to change its temperature under the thermo-electric pile.

Powerful electrization of feeble persons may cause a general chilliness of the extremities that may last for hours. A sensation of having caught cold has been known to follow strong peripheral faradization.

Whether the action of the current on the retina and on the auditory and gustatory nerve is direct or reflex has been long disputed. Our researches induced us to the belief that electricity acts on the nerves of special sense both reflexly and directly. That the gustatory nerve can be treated by reflex action, we have shown in a variety of experiments with both currents. Sensitive patients appreciate the sour or metallic taste when the application is made to the lower part of the spine or to the arms. Similarly, flashes before the eyes may be produced when the electrodes are so placed that the current cannot traverse directly the region of the brain where the optic nerve takes its origin. Excitation of the auditory nerve by reflex action is not so easily demonstrated, but tinnitus aurium sometimes follows electrization of the spine and neck, and it is not unfair to infer that it is the result of reflex excitation.

In thus admitting the possibility of exciting the nerves of special sense, we do not desire to give the impression that the ordinary physiologic excitation of these nerves under electricity is purely of a reflex character; on the contrary, we have shown already, in the chapter on Electro-Conductivity, that the current penetrates the brain and goes through those parts where the optic nerves originate, and also must pass through the labyrinth and act directly on the auditory nerve.

In reference to the reflex effects of electricity these two considerations are of importance:

1. That galvanic currents operate much more powerfully by reflex action than the faradic. The partial explanation of this fact which we offer is that the greater chemic power of the galvanic current, due to its acting always in one direction, causes it to operate more distinctly on the nerves than the faradic current. This fact of the superior reflex capacity of the galvanic current is one of high practical import in the treatment of disease, and explains in part, if not entirely, the dangerous, or at least unpleasant, effects that sometimes follow careless or ignorant galvanization in cerebral hemorrhages and other irritable conditions of the central nervous system.

Althaus has recorded a case of anæsthesia of the fifth pair of cerebral nerves of a most profound character, in which there was a complete absence of cerebral symptoms—dizziness, flashes of light, and galvanic taste—whenever a galvanic current of twenty cells was applied to the face. A current from 30 cells, which on a person in health would cause powerful flashes, a hissing sound in the ears, feeling of heat, and perhaps perspiration, caused in this patient only a slight sensation of giddiness and metallic taste and phosphoric odor.

This remarkable case is a strong argument in favor of the opinion that the results of electrization of the head and the results of experiments like those of Erb are due in part, if not entirely, to reflex action.

It is possible that in the above case the portion of the brain where the optic nerve originates was also diseased so as to render it insensible to electric excitation.

2. These reflex effects occur in all the applications of electricity of either form, and complicate the direct effects. The physiologic and therapeutic effects of electrization of the brain, the eye, the ear, the cervical sympathetic, the spine, the trunk, and the periphery, everywhere are a complex resultant of both direct and reflex electric action. Localized electrization, strictly speaking, is an impossibility, however closely together the electrodes may be placed, and however distant from the great nerve tracts and nerve centres the spinal cord must take cognizance of the impression made by the current on the sensory nerves, and other parts and organs must share in the effects, for better or for worse. It is for this reason that caution is requisite even in faradizing the paralyzed muscles in recent hemiplegias and in active myelitis.

The very remarkable results that follow general faradization—a method to be subsequently described—are to be accounted for in part by reflex actions, which are continually taking place during all stages of the application.

Practical Application of these Physiologic Principles to Electro-Therapeutics.—With the above facts and reasonings before us we are prepared to intelligently appreciate the effect of electricity on nutrition. We do not profess to have exhausted the *rationale* of the complex action of electricity on the tissues, but to have indicated the leading principles by virtue of which it affects the nutrition of the animal body. Many discoveries may yet be in store for us in this department; it may be shown that ozone is generated in the tissues with every passage of the current, and that this ozone is taken into the circulation; the subtle and intricate chemistry of electrolysis of living tissues in their secondary and tertiary, as well as their primary changes, may be unfolded to the vision of the future, and what we now see in a glass darkly posterity may behold face to face; but sufficient is known to explain in a most interesting way the unrivalled effect of electricity on the nutrition.

An objection sometimes brought against electricity is that we do not understand its action; and yet in the whole round of stimulating tonics there are but few whose action can be so well explained as that of electricity. Who knows how arsenic feeds the nervous system or how quinine breaks an attack of chills and fever? Why does oxide of zinc act with magic force in chronic alcoholism? How does opium produce sleep and relieve pain; and who has entered into the mysteries of anæsthesia?

Animal nutrition is a process of enormous complications. There is no single chemic change at which one can point and declare that this explains the growth and sustenance of the body; but there are nameless and numberless phenomena every moment going on in the living tissues, and as a result of all these, in their infinite play and combination, the body lives, moves, and has its being. Electricity in passing through the body modifies many or all of these processes, and thus modifies nutrition. As a resultant of the complex physical, chemic, and physiologic action of electricity on the tissues, there is increased development and growth.

Experimental and Clinical Proofs of the Effect of Electricity on Nutrition.—We have studied the effect of electricity in great detail on animals and on man. On animals our experiments have been confined to the effects of general faradization; on man we have studied the effects of both localized and general treatment.

Of a litter of four puppies, we submitted two to general faradization every other day, for eight minutes each, and two were not so treated, all having an equal chance at their mother's breast and nothing besides. All the puppies were carefully weighed at the beginning and at the end of the treatment, which lasted for four weeks. It was found that both of the pups that had been electrized weighed more than the puppies that had not been electrized; all had, of course, increased in weight, but of those electrized one had increased four ounces and the other ten ounces more than his fellows that had not been electrized. The difference of size in favor of the puppies that were electrized was so marked and so easy so see, that without great difficulty one who had never seen them succeeded in picking out, from ocular inspection, those that had been treated, and that too in the evening, and in a bad gas-light. It was observed during the treatment that the puppies which were electrized became ravenous, and sucked with greater energy than their less-favored companions.

The method of treating the pups, we may remark, was to put them on a sheet of copper, while the hand of the operator or a sponge-electrode was rubbed all over the surface of the body, previously moistened.

The details of the experiments, prepared by our assistant, Dr. J. W. Sterling, who made the applications, are as follows:

July 1—Weight of four pups, ten days old:

Two black pups (weight each)..... 1 lb. 6 oz.

Two yellow pups, weight of one .... 1 lb. 3½ oz.; other, 1 lb. 2½ oz.

July 1—Commenced general faradization, each application about eight minutes.

Applied it to one of the black pups, weight 1 lb. 6 oz., and the lightest of the yellow pups, weight 1 lb. 2½ oz.

Continued the application four weeks, making three each week.

July 28—Weighed the pups after twelve applications.

One black pup (general faradization)	3 lbs. 7 oz.
One black pup (no faradization)	2 " 13 "
One yellow pup (general faradization)	3 " 0 "
One yellow pup (no faradization)	2 " 12 "

Making a clear gain for the *electrized pup* (black) of 10 oz., for the yellow electrized pup 4 oz.

This we believe, was the first comparative experiment of this kind made with the faradic current. Subsequently, we repeated the experiment on a litter of three rabbits. Two were faradized every other day; to the other no treatment was given. At the end of six weeks the one not treated was visibly larger than either of those that were treated. We explained this unexpected result by the theory that the current had been used too strong and too long for the young and delicate animals. The experiment was carried on while we were in the country, and the details were intrusted to those who were utterly incompetent for their duties. The directions given were to put the feet of the rabbits in a basin of tepid water, and after well moistening the back of the neck to pass the current through for ten minutes; on account of the non-conductivity of the dry hair of the rabbit, general faradization was almost impossible.

Legros and Onimus electrized with the galvanic current some puppies for a quarter of an hour every day, by placing one of the fore-paws and one of the hinder-paws in tepid water connected with the electrodes. At the end of six weeks those that had been electrized weighed more than the same lot that had not been electrized; and this difference was perceptible to simple inspection; one was galvanized with the ascending, and the other with the descending current.

The effect of faradization on nutrition is powerfully illustrated by the experience of those who habitually or frequently apply general faradization through their own persons, taking an electrode in one hand, and applying the other to the body of the patient. In this method the current passes through both arms, and vigorously contracts the muscles.

The permanent effects of the current on the person of the operator are:

1. To cause very marked and sometimes rapid growth of the muscles of the arms.

The explanation of this phenomenon is sufficiently easy. The muscular contractions that are produced by the current in its passage through the arms cause increase of the local processes of waste and repair, and accordingly the muscles increase in size, just as they naturally do under the influence of any other form of active or passive exercise. This mechanic explanation would be of itself sufficient, but, in addition, it is entirely probable that the electric current exercises a direct and specific influence on the nerve-branches, which effect is expressed by the increased size and vigor of the muscles through which the nerves ramify.

During our first experimental attempts in the treatment of disease by general electrization, we observed a decided increase in the development of the muscles of the arm. It began to force itself on our attention a few weeks after we commenced to give special attention to general electrization, and at the present time it is fully as marked as ever. Both arms have not only increased much in size by actual measurement, but also correspondingly in strength and hardness. This effect is observed in the arm and forearm, but most decidedly in the muscles which, from their position or nerve supply, contract most readily and vigorously when the current passes from hand to hand, such as the deltoid, brachialis anticus, biceps, and the flexors and extensors of the forearm. This same effect has been noticed, to a greater or less degree, by our students and, so far as we have been able to ascertain, by others, who have employed electricity through their own persons for any considerable period. This development of the arms seems to progress up to a certain limit, at which it remains.

2. A very gradual but decided tonic influence on the system.

This effect is so exceedingly slight that in a very hardy and vigorous person it would not be recognized. That the current, in passing from hand to hand, so frequently and so long, should, in the course of time, mildly affect the general system, is entirely probable. Like any other muscular exercise of the arms—gymnastics and the use of the clubs—its influence, so far as it goes, must be positively toning and beneficial to the constitution.

The influence of the different forms of electricity on the nutrition of muscles was extensively studied by Debedat,* of Bordeaux, whose experiments were undertaken in consequence of the discussion at the Congress of Electrotherapy at Frankfort, in 1891, at which Möbius declared that the effects observed from the use of electricity were the result of suggestion. Animals were selected as not being susceptible to suggestion, and an effort was made to determine if there were any actual increase of muscular fibrillæ or any exaggeration of the special properties of muscles under the influence of the current.

A study of muscular nutrition and the relation of muscular contraction to the circulation led to the conclusion that functional inertia of muscles has a most injurious effect on their nutrition and on the general circulation. A comparison of natural exercise and that produced by electricity showed that the circulatory phenomena of muscular contraction are the same for natural and for electric excitation. This establishes the advantages of electric gymnastics, and shows that the effects of electricity are real, and not the result of suggestion.

Effects of Electricity on Bacteria.—Cohn has experimented with electricity on bacteria.† Currents from two powerful elements, sterilized the nu-

* Archives d'Électricité Médicale, February 15th, 1894.

† Med. Press and Circular, June 9th, 1880.

tritive solution completely at the positive pole in twelve to twenty-four hours, so that afterward the bacteria produced did not increase. At the negative pole the action was weaker, the liquid not being completely sterilized. At neither of the poles were the bacteria killed, and when brought into another nutritive fluid they developed normally.

In the experiments of Burci * and Fraseani with a current of 5 to 10 milliamperes, the iodine from a solution of iodide of potassium killed in fifteen to thirty minutes both streptococci and staphylococci.

Physiologic Effects of Magnets.—Peterson † and Kennelly, in elaborate experiments at the Edison laboratory, conclude that the human organism is in no wise appreciably affected by the most powerful magnets known to modern science; that neither direct nor reversed magnetism exerts any perceptible influence upon the iron contained in the blood, upon the circulation, upon ciliary or protoplasmic movements, upon sensory or motor nerves, or upon the brain.

Physiologic Effects of Alternating Currents.—Much attention has of late been given to alternating currents, and D'Arsonval's ‡ recent studies on nerves and muscles enables him to suggest the following laws: 1. Nerve excitability is brought into play especially by the rapidity and extent of the variation of the potential. The quantity of the current plays a secondary rôle. 2. Muscular excitability is brought into play by the quantity of the current and the height of the variation of the potential—*i.e.*, the physical energy of the excitation. 3. Alternating currents with sinusoidal variation do not produce a sharp shock on the system. With low frequency they give neither pain, muscular contraction, nor electrolysis, and their influence on the economy consists in an increase in the absorption of oxygen and the elimination of carbonic acid. Gradually increased they provoke energetic contractions; but these, by reason of the regularity of the current, while of equal intensity, are much less painful than the contractions from the induced current. By this means the gaseous exchange can be increased one-fourth without ill effect. Hence, according to Gautier, Larat, Bouchard, Kellogg, and others, it is very useful in diseases of perverted nutrition.

In his experiments D'Arsonval produced currents of great frequency, and by means of auto-conduction was enabled to successfully submit the body to the influence of electrization. He used the resonator of Hertz, which can give up to one thousand million vibrations a second. That such a current has an influence on the organism is shown by its action on an interposed incandescent lamp. It is known that these alternating cur-

* Revue Internationale de Bibliographie, Beyrouth, August 10th, 1894.

† "Some Physiological Experiments with Magnets at the Edison Laboratory," New York Medical Record, December 31st, 1892.

‡ Revue Générale des Sciences pures et appliquées, Paris, May 15th, 1894, and Revue Internationale de l'Electrothérapie, Paris, April, May, and June, 1893.

rents are distributed especially on the surface. How account, then, for the induced currents exhibited in the organism, especially in the nervous centres? D'Arsonval does this by a theory, attributing to different nerves different modes of excitation, by which they are found in unison with electric waves only for vibratory periods comprised in fixed limits. Above and below these limits no electric irritation will take place. If this is so, there are limits for each class of nerve, and this is exactly the result of his experiment. He makes use of apparatus for obtaining currents of great frequency and feeble intensity (Fig. 49).

A continuous current of great intensity (A and B) puts in play a Ruhmkorff coil; the two ends of the coil lead to the internal armatures

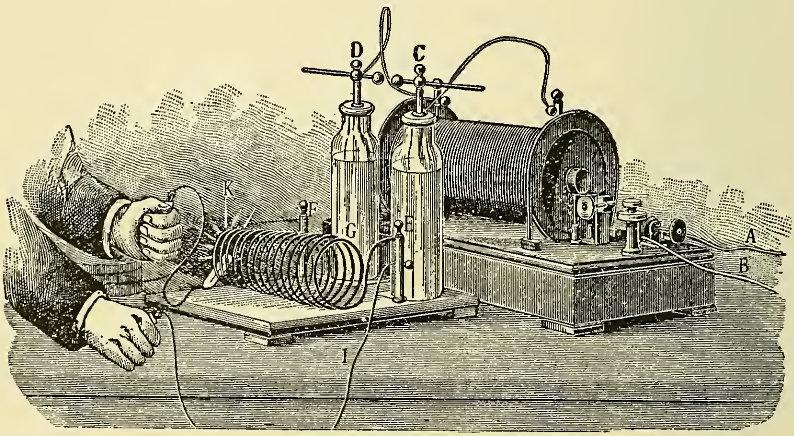

FIG. 49.—Method of Obtaining Currents of Great Frequency and Feeble Intensity. (D'Arsonval.)

(D and C) of two Leyden jars; the external armatures (E and F) of these jars are united by the solenoid (G) and by the cord (I), in the circuit of which is interposed the incandescent lamp (K) and the body of the operator. This apparatus may be used with entire safety. The theory of induced currents in the tissues is supported by the experiment illustrated in Fig. 50.

The operator holds between his arms the solenoid attached to the current of high frequency.

The current induced in his arms by the vicinity of the solenoid is sufficient to render incandescent a 2-ampere lamp, completing the circuit formed by the arms. In the same manner the whole body may be enclosed in a large solenoid and subjected to the action of the current. It has been found that the vaso-motor system is most highly influenced, an increased respiratory combustion takes place, as is shown by the increased heat radiation, without, however, any rise of body temperature.

These demonstrations and the demonstrations of Tesla seemed to indicate that enormous voltages were harmless to the human body if only they could be made to alternate with sufficient rapidity, and men were astounded at the spectacle of a lecturer placing himself in a circuit carrying a current alternating hundreds of thousands of times per second, at a pressure of many thousands of volts.* "These experiments, coming not long after the accounts of the execution of criminals by electricity in this country with pressure of 1,700 volts, and compared with the fatal accidents to workmen engaged upon electric-light cables at 1,000 volts, made it

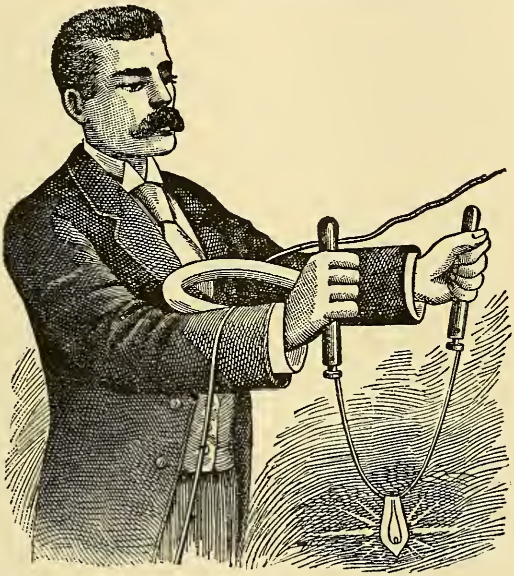

FIG. 50.—Production by Induction of Currents of High Frequency in the Human Body. (D'Arsonval.)

seem as though the rapidity of alternation was the factor which protected Tesla from injury by the enormously high voltages which he was handling. Such an inference may not be a proper one, for the following reasons: 1. A Leyden jar discharging through the body produces effects which are painful and severe, as all who have felt them will agree; but yet this is a discharge of high frequency of alternation; in fact, it is by the Leyden jars in the circuit that the oscillatory character and the rapid alternation of the discharge are determined. Lodge gives the rate of oscillation for a pint-sized jar at ten millions per second.

"2. The high frequency and high potential discharge of Tesla's apparatus are not altogether harmless, but can produce severe shocks and can kill small animals, as Elihu Thomson has shown. The discharge

* Annual of the Universal Medical Sciences, vol. v., 1894.

from the terminals of such an apparatus can produce severe muscular contractions, even with the resistance of a considerable air space interposed in the circuit.

"3. It is doubtful whether D'Arsonval's estimation of the magnitude of the current of his apparatus is correct.

"The incandescence of a lamp-filament with currents of high frequency has recently been under discussion, and a very satisfactory explanation of the phenomenon has been forthcoming. It is well known that for alternating currents the resistance of a conductor is greater than it is for steady currents, and the increase of resistance rises rapidly as the rate of alternation becomes greater; and with frequencies approaching one million per second, the effective resistance of the lamp used would be raised enormously. This would require the energy needed to bring it to incandescence to be applied at a proportionately higher voltage, while the magnitude of the current would be lessened in an equal degree. For example, the energy of 2 amperes at 100 volts is the same in amount as that of 0.02 of an ampere (20 milliamperes) at 10,000 volts. It is therefore probable that the current which raised the 2-ampere lamp to incandescence was very much less than 2 amperes—probably only a few milliamperes; and herein lies the whole pith of the question. The experiments with high-frequency currents of high tension are harmless if the magnitude of the current is small; and as the high potential is, in fact, obtained at the expense of the current, this latter diminishes in proportion as the potential is raised by each successive step up in the transforming apparatus. For the present it may be taken as not yet proved that high frequency of alternation can render electric currents harmless; and it may still be accepted that the effect produced by the passage of a current through living tissues depends primarily upon the magnitude of the current as measured in amperes, which is made to traverse them, and upon its density or concentration therein."

Other contributions to this subject have been made by Gautier and Larat,* and Dawson Turner,† while Damian, of Paris, has demonstrated that under the influence of the high-tension currents of static electricity the heart's action is stimulated, the temperature raised, and the urea increased.

* La Semaine Médicale, Paris, September 21st, 1892.

† Practitioner, London, July 15th, 1892.

ELECTRO-THERAPEUTICS.

ELECTRO-THERAPEUTICS.

CHAPTER I.

HISTORY OF ELECTRO-THERAPEUTICS.

Electro-Therapeutics is the science that treats of the study of electricity in its relation to disease.

It includes both electro-medicine and electro-surgery, or, as they are more commonly termed, medical and surgical electricity. Under medical electricity are included electro-diagnosis, or electro-pathology, as it is sometimes termed, and electro-therapeutic anatomy.

The earliest history of electro-therapeutics, as of many other departments of medicine, is shrouded in obscurity. It dates back to a mythical and legendary age, before mankind had been trained to habits of scientific criticism, while yet history was a mass of traditions, and rumor was a substitute for truth.

It is said that centuries ago the negresses of West Africa were accustomed to dip their sick children in water where lay the electric fish called the torpedo. The remedial powers of electricity were also referred to by Pliny and Dioscorides. Scribonius Largus, a physician of the time of Tiberius, was accustomed to prescribe the same remedy in the treatment of gout. As long ago as the days of Pliny, necklaces of amber were worn by women and children for the sake of their supposed remedial powers.

The mysterious power of the magnet was known to the ancient world, but we have no reason to believe that it was ever extensively resorted to by them for the cure of disease. In Europe, during the middle ages, the loadstone was used in the treatment of disease, and although its successes were trifling it aroused the professional attention and received extravagant praise from the distinguished Paracelsus. About the middle of the eighteenth century, Maximilian Hehl, of Vienna, and others, excited a new and more successful interest in the use of magnetism in disease by the manufacture and employment of artificial magnets.

The real history of electro-therapeutics may be divided into three eras: the Era of Franklinic Electricity, including the early and crude experiments with the frictional machines and the Leyden jar; the Era of Galvanization, beginning with the publication of the discovery of Galvani, in 1791, and including the invention and medical employment of the voltaic pile; the Era of Faradization, beginning with the discovery of induction, in 1831–32, and including all that has since been accomplished in the department of localized and general electrization.

In the first era only franklinic electricity was used, because it was the only form that was known; in the second era, both franklinic and galvanic electricity were used, since the latter supplemented, but not entirely supplanted, the former; in the third era, all three forms of electricity—franklinic, galvanic, and faradic—were brought into requisition, and the uses of the first named especially have been extended and improved.

The Era of Franklinic Electricity.—The records of this era, though not extensive, are yet both interesting and suggestive. It is probable that in this, as in the second era, very much was attempted and even accomplished in this department that has never been recorded in permanent medical literature, and therefore could never become of value to science.

In 1730 Etienne Grey first observed divergence of the hairs in an isolated subject put in communication with static electricity.

The same experiment was repeated by Abbé Nollet and Du Fay. Du Fay observed the electric sparks drawn from the isolated subject.

Nollet says, "I shall never forget the surprise which the first electric spark ever drawn from the human body excited both in M. Du Fay and myself."

Sparks were then drawn from the body in various shapes—one of which was called the electric kiss; other forms were known as the "electric star," "electric rain," and so forth. The drawing of the sparks constituted a great source of amusement in the society of the period.

In 1743 Kruger d'Helmstadt suggested that these electric sparks might be made of service in therapeutics.

In 1744 Kratzenstein, a German physician, recorded a case of cure of paralysis of the fingers by sparks drawn from a frictional apparatus.

In 1746 the discovery of the properties of the Leyden jar by Muschenbroek gave physicians a new means of using electricity in the treatment of disease.

In 1749 Jallabert,* of Geneva, published a treatise on the medical use of electricity, in which he reported a cure of long-standing paralysis of the right arm, resulting from injury, by electric sparks. The cure was brought about in two or three months, and may perhaps be regarded as the first decided and unquestioned result of the kind that was obtained in the early days of electro-therapeutics.

In 1750 Nebel showed that contraction of the muscular tissue was produced by electrization.

* "Experiences sur Electricité," Paris, 1747.

Bohadtch, of Bohemia, also recommended electricity, especially for the treatment of hemiplegia.

In 1753 Lindhult, a Swedish physician, reported a cure of epilepsy by electricity.

In 1754 Sulzer made his famous experiment on the tongue with zinc and copper plates. He did not, however, pursue his experiments, and it was reserved for Galvani and Volta to discover galvanic electricity.

In 1755 De Häen reported a large number of electric cures of paralysis, spasmodic and other nervous affections, and also of suppression of the menses, and St. Guy's dance. About this time, also, Schaeffer and Nebel published cures of rheumatism, toothache, hypochondria, paralysis of the optic nerve, and of intermittent fever and neuralgic pains. Between 1750 and 1757, cures of paralysis were reported by Brydone, Bertholon, Sauvages of Montpellier, and Spry, the latter of whom cured a case of lockjaw and paralysis.

The position that electro-therapeutics held at that time, and the hopes that were entertained of it, is very well represented in a little treatise by the eminent divine, Rev. John Wesley, entitled, "The Desideratum; or, Electricity Made Plain and Useful, by a Lover of Mankind and of Common Sense." 1759.*

In this treatise the author anticipates, in a sort of theoretical way, very much that has since been demonstrated, both in electro-physics and electro-therapeutics, and with surprising accuracy. In the preface he acknowledges his indebtedness "to Mr. Franklin for the speculative part, and to Mr. Lovett for the practical." He also mentions as authorities, Dr. Haadley, Mr. Wilson, Watson, Freke, Martin, Watkins, and the *Monthly Magazine*, whence we may conclude that even at that early day the subject was exciting much interest, but more among the laity than in the profession.

From the tone of the book it is clear that the Faculty, as Wesley calls the profession, were disposed to despise electro-therapeutics and to reject its claims, as they have been ever since, until within a few years, and consequently they suffered what was really valuable in medicine to be monopolized by the laity.

The mind of Mr. Wesley, as the world knows, was of the practical sort, and in this treatise he does not suffer himself to be carried away into gross hyperbole or serious untruth. He expressly disclaims any idea of regarding electricity as a panacea, but says what we now know to be true, that it is indicated in a wide range of disorders; but that if any one agent should ever become a panacea, electricity stood the best chance of being that agent.

Evidently ignorant of Franklin's invention of lightning-rods, in 1775, he suggests that buildings and ships might be saved from the effects of

* This treatise has been republished by Baillière, Tindall & Cox, London, 1871.

lightning, by "upright rods of iron, made sharp as needles and gilded to prevent rusting," and connected with the earth. He further suggests that the northern lights are of electric origin.

He gives the following list of diseases in which electricity is of service, with a number of illustrative cases, most of which are very imperfectly detailed. It will be observed that most of these diseases are still treated electrically, and with greater or less success. It seems from the list that the treatment of diseases of the skin by electricity is simply another attempt to effect what was accomplished with success more than a century ago.

All these conclusions of Wesley and his contemporaries were, however, based on experiments made with franklinic electricity. The world was to wait forty-one years for the voltaic pile, and seventy-two years for Faraday to discover induction.

"Agues, St. Anthony's Fire; Blindness, even from a Gutta Serena; Blood Extravasated; Bronchocele; Chlorosis; Coldness in the Feet; Consumption; Contraction of the Limbs; Cramps; Deafness; Dropsy; Epilepsy; Feet violently disordered; Felons; Fistula Lacrymalis; Gout; Gravel; Headache; Hysterics; Inflammations; King's Evil; Knots in the Flesh; Lameness; Leprosy; Mortification; Pain in the Back, in the Stomach; Palpitations of the Heart; Palsy; Pleurisy; Rheumatism; Ringworms; Sciatica; Shingles; Sprain; Sore Feet; Swellings of all kinds; Throat sore; Toe hurt; Toothache; Wen."

In 1763 Watson cured a case of general tetanus in a young girl of seven years. Although the fame of the cures wrought by electricity attracted crowds of invalids, yet by the ignorant and superstitious it was confounded with witchcraft, and the aid of the priest was invoked to save them from its baneful influence.*

Abbé Sans published a work on the medical use of electricity, and recorded important cures. According to this authority, there were seven different methods of employing static electricity—"an electric bath, drawing sparks, by irroration, friction, insufflation, exhaustion, and commotion." Injurious and negative as well as favorable results were sometimes reported. Thus Dr. Hart brought on paralysis in a girl, and Abbé Mazras excited epilepsy in one of his patients. Benjamin Franklin failed to cure the invalids that flocked to him after his great discovery, and Abbé Nollet, after many years' experience, was compelled to admit that he had seen but little permanent benefit from electricity.

Symptoms Only Treated in these Early Experiments.—In these early and many of the later experiments, not disease, but the results of disease, were both studied and treated. When electricity was applied, it was to the symptoms and not to the pathologic condition; hence the enormous blunders and frequent failures of the early electro-therapeutists. The

* "A Treatise on Medical Electricity, Theoretical and Practical," by J. Althaus, M.D., 1870, p. 284.

symptoms most treated, and in the treatment of which the greatest hopes were entertained, were blindness, deafness, paralysis of motion, symptoms which are now known to depend, in very many instances, on pathologic states, which are in their very nature as incurable as death itself. Still further, the applications were made to the seat of the symptoms exclusively, instead of to the seat of the disease, and this mistake helped to swell the number of the failures.

Physiology and pathology had not yet reached that degree of strength and breadth of sureness to furnish good foundation on which to erect the science of electro-therapeutics, and withal the appliances for generating electricity were bulky and untrustworthy, and methods of electric measurement not yet devised.

Electro-therapeutics was therefore baffled in its first attempts at growth, through lack of needful support from allied and fundamental sciences; it must wait for physics, for physiology, for pathology to come to its rescue, which in due time they have done and are now doing.

In 1773 and 1778 Maduyt presented memoirs* on the subject, in which he affirmed in his report that electricity was a remedy of vast and varied powers; that it had a positive and very beneficial influence over nutrition; and that it equalized the circulation, materially affected the pulse, the perspiration, and the secretions; and was surprisingly efficacious in the treatment not only of paralysis, but also of other conditions, such as constipation and œdema. This report aroused considerable interest in electro-therapeutics on the part of the profession, and for a season the application of franklinic electricity became extensively popular. In 1777, Cavallo published a work† which excited considerable attention. He reported cures of epilepsy, paralysis, chorea, deafness, blindness, rheumatism, glandular enlargements, and recommended electricity as a means of artificial respiration.

On the theory that medical substances might be combined with electricity, Pivati, of Venice, placed in his electric machine a glass cylinder, filled with Peruvian balsam, and Giuseppe Bruni affirmed that, by the same arrangement, filled with purgatives, he had produced the same effect on an electrified patient as though the remedy had been administered internally.‡

In 1783 Wilkinson presented the results of some experiments with electricity in England. Although the fame of the cures wrought by the

* "Mem. sur les effets généraux, la nature et l'usage du fluide électrique considéré comme médicament," lu en décembre, 1778, à la Société royale de médecine. "Mem. sur les différentes munières d'administrer l'électricité, et observations sur les effets que ces divers moyens ont produits," lu en décembre, 1783, à la Société royale de médecine.

† "A Complete Treatise on Electricity, in Theory and Practice, with Original Experiments," Londres, 1777. Id., "Medical Electricity," Londres, 1780.

‡ Althaus: Op. cit., p. 287.

new remedy attracted thousands of the people, yet by the ignorant and superstitious electricity was confounded with the spirit of evil.*

Of the seven methods of employing static electricity recommended by these early experimenters, but three were in common use. These were: the electric bath, electrization by sparks, and shocks from the Leyden jar. Some twenty years ago static electricity came into more general and effective use—more especially because of the practical suggestion of Vigoroux, of Paris, to enclose the plates, thereby keeping them always dry and ready for immediate use.

The Era of Galvanization.—Animal electricity was discovered by Galvani in 1786, and made public in 1791. It was by the experiments of Galvani that Volta was stimulated to investigate the subject of electricity. He denied the existence of animal electricity which Galvani had discovered. One of the most important fruits of the discussion that arose between them and their respective followers was the construction of the voltaic pile, which for many years physicians employed, with various alternations of failure and success, in the treatment of disease.

In the period intervening between the discovery of animal electricity by Galvani and the construction of the pile of Volta, electricity was applied to the body by means of metallic plates, joined together by a metallic arc. Sometimes these were simply placed against the skin, and sometimes over spots denuded by a blister.†

In 1792 Behrend, Creve, and Klein suggested the use of galvanism as a means of distinguishing real from apparent death. The first attempts to make galvanism of practical service in the treatment of disease were made by Professor Loder, of Jena. The results of his experiments were unsatisfactory.

In 1793 Hufeland and Reil advised the use of the galvanic current in paralysis.

In 1796 Pfaff advised the same remedy for amaurosis. None of these authorities spoke from much personal experience.‡

In 1797 Alexander von Humboldt § suggested, on theoretical grounds, the use of galvanism in paralysis, rheumatic pains, and diseases of the eyes.

Valli actually restored to life, by galvanism, frogs and fowls that had been nearly suffocated.‖

The voltaic pile, invented in 1800, marked an era in the medical use of the galvanic current, because, with all its imperfections, it was vastly

* A. Tripier: "Manuel d'électro-thérapie, exposé pratique et critique des applications médicales et chirurgicales de l'électricité, Paris," 1860.

† Tripier: Op. cit., p. 262.

‡ Tripier: Op. cit., p. 263.

§ "Versuch über die gereizte Muskel und Nervenfaser," Berlin, 1797.

‖ "Expérience sur le galvanisme, traduit par Jadelot," Paris, 1799.

superior, for therapeutic purposes, to the metallic plates that had previously been employed during the period which had elapsed since the discovery of Galvani. It was at once employed by Loder, in Jena, by Grapengiesser,* Bischoff, and Lichtenstein, in Berlin, and by Haller, in Paris, chiefly in cases of paralysis.

In 1801 Augustin, of Berlin, published a treatise on galvanism, in which he reported results of treatment of paralysis by applying the negative pole to the central end of the nerve, and the positive to the peripheral. Professor Schwab experimented with the voltaic pile in cases of deaf-muteism. In 1802 Sigaud de la Fond published a work in which he recommended franklinic electricity for nearly every form of disease. In 1804 Aldini, a pupil of Galvani, published a treatise on galvanism, in which he theoretically recommended it for deafness, insanity, and amaurosis, and also to produce artificial respiration.†

Even during this era, and for many years after the invention of the voltaic pile, franklinic electricity was still employed.

In 1817 Dr. Thomas Brown, of Albany, published a work entitled "The Ethereal Physician," in which he recommended franklinic electricity for paralysis, tic douloureux, epilepsy, chorea, and in a large variety of disorders.

In 1818 Dr. Everett, of New York, published something on the use of electricity in medicine that was based on experience that he had derived with the apparatus of Dr. Brown.

In spite of all these endeavors on the part of scientific men to give importance and dignity to the cause of electro-therapeutics, it failed to fulfil the extravagant expectations that had been formed of it; a reaction followed, and it fell into disrepute. Electricity had been tried for a wide range of diseases, but partly on account of the inconstancy of the voltaic pile, and partly through the ignorance of the operators, it was found to be a most uncertain remedy. It was confounded with mesmerism, which at this period came into notoriety, and for a time it shared its fate.

Many of the Early Experiments Made by the Laity.—It will be seen by a glance at the above-mentioned names that the earliest experiments in electro-therapeutics were made by the laity. A science that now commands some of the best brains of civilization was born among the humble and the lowly. It was cradled in ignorance and reared and fostered by those who, however eminent in other walks, knew little or nothing of medicine. Chemists, physicists, priests and paupers, monks and mountebanks, were in the eighteenth century the leading authorities in electro-therapeutics. If there were those at this time who had faith in the coming of a better day, when electro-therapeutics should be a recognized and per-

* "Versuche den Galvinismus zur Heilung einiger Krankheiten anzuwenden," Berlin, 1801.

† "Essai théorique et expérimenta sur le galvanisme," 1804.

manent part of the medical science, it was their misfortune to die without the sight. Not until the close of the eighteenth century were the great discoveries of Galvani and Volta revealed to the world, which was to work and wait for at least half a century before it should see even the beginning of the fulfilment of its hopes. Some of the great sciences, like some of the great religions, have had the humblest origin.

Of the early history of electro-physics, Whewell* thus remarks: "At such a period a large and popular circle of spectators and amateurs feel themselves nearly upon a level in the value of their trials and speculations with the more profound thinkers; at a later period, when the subject is becoming a science, that is, a study in which all must be left far behind who do not come to it with disciplined, informed, and logical minds, the cultivators are far more few, and the share of applause less tumultuous and less loud. Electricity, to be now studied rightly, must be reasoned upon mathematically."

What Whewell here says of electro-physics may just as truly be applied to electro-therapeutics.

In the earlier experiments, the philosopher and the fool were pretty nearly on the same level in their knowledge of the application of this subtle force to the treatment of diseases, with this advantage on the side of the fool, that through the very excess of his ignorance he dared and ventured where the philosopher knew just enough to fear to tread.

It was, as we shall see, a long time before electro-therapeutics should be gradually developed into a science of sufficient positiveness to command the attention of men of science for its own sake, and to excite the despair of the ignorant.

Here, as in all other realms of investigation, the development is from simplicity toward complexity, from generals to specials, and from truths that are common to all classes, to truths that only a few specialists can thoroughly master. We are reminded here of the beautiful thought of Thoreau. When reproached for his exclusiveness and love of solitude, he replied: "It is not so much that I love to be alone, as that I love to soar, and the higher I ascend, the company grows thinner and thinner, until at last I am left almost alone."

Strikingly this principle has been illustrated even in the most recent history of electro-therapeutics, both in Europe and America. A field now occupied by some of the ablest scientists of Germany, England, and France, was formerly crowded with lawless intruders.

When we began to write on this subject in 1868, a tide of inquiries at once set in upon us, from all parts of the country. The authors of these letters, with some few exceptions, we have never seen; but, judging from the style of composition and the character of the inquiries, they were as a rule comparatively ignorant, and belonged to the lower strata of the pro-

* "History of the Inductive Sciences," 2d ed., vol. ii., p. 200.

fession. Letters that we received later and now receive, evidently come from many of the best men in the profession. As the science develops, brains and culture are attracted to it. In our large cities, those who are studying this subject are among the most promising names in science.

In 1825, Sarlandière proposed the employment of acupuncture needles in galvanization, so that the current could be more exclusively and definitely localized on the desired nerve or organ. This method of treatment was called electro-puncture.* He used for this purpose franklinic electricity. Subsequently Magendie successfully experimented with galvano-puncture in neuralgia, paralysis, and other nervous diseases.

The discovery of electro-puncture was the beginning of the science of electro-surgery, a department which at that time commanded a wider interest than the medical use of electricity, and which has now a most important position in science.

Gerard and Pravaz suggested, and Pétrequin and Ciniselli succeeded in curing aneurism by galvano-puncture. Subsequently galvano-cauterization has been investigated by Steinheil, Middeldorpff (1859), Amussat, Althaus, Byrne, ourselves, and many others.

In 1826 Baumé published in London a work on galvanism, which two years later reappeared in a different form, and was translated into French by Fabre Palaprat, who was the first to use the galvanic current in electro-puncture. The modern and practical development of galvano-therapeutics will be found illustrated in the succeeding pages of this work.

The Era of Faradization.—The publication of the discovery of inductive electricity by Faraday, in 1831–32, changed the whole course of electro-therapeutics. On the basis of this discovery electric machines were constructed that were both more reliable and more convenient than the ordinary voltaic pile. The first magneto-electric machine was constructed by Pixii in 1832, and was first employed in the treatment of diseases by Neef of Frankfort. Afterwards electro-magnetic (volta-electric) machines were constructed by Neef, Clarke, Stöhrer, and others, which from time to time have been variously modified by a large number of experimenters in different countries.

From this time electricity in the form of faradization began to be extensively and indiscriminately employed, both in this country and in Europe. It was used by the laity as well as by the profession, though at first without any recognized method, and without any very clear ideas of the indications for which electrization was adapted. Since that time four distinct methods of medical electrization have been introduced, in which the galvanic as well as the faradic current have been appropriated, and under one or the other of which may be classed all the applications of faradic or galvanic electricity that have since been employed. These

* "Mem. sur l'électro-puncture," Paris, 1825.

methods are localized faradization, localized galvanization, general faradization, and central galvanization.

History of Localized Faradization.—The history of localized electrization is identified with the name of Duchenne, whose experiments and discoveries have given such an impetus to this important and growing department. Duchenne was not, however, the first to employ localized faradization. Prior to his time, faradization had been used by Masson in France, and Neef of Frankfort; and in this country it has been employed by the profession and by the laity from the period of the first popularization of machines of induction.

Even as early as 1843 localized faradization was used in this country side by side with general faradization, though, like the latter, it had received no distinct nomenclature, and was indiscriminately recommended and unscientifically applied.* The two methods, localized and general, were frequently confounded, and both were known under the vague term, "electrifying." Duchenne's earliest attempt to call the attention of the profession to this subject is thus recorded in his own words:

"De l'art de limiter l'excitation électrique dans les organes sans piquer ni inciser la peau, nouvelle méthode d'électrisation appelée électrisation localisée, et dont les principes, résumés dans une note adressée en 1847 à l'Académie des Sciences, ont été développés et publiés dans les archives générales de Médecine en juillet et août 1850, et février et mars 1851." In 1855 he published his chief work, "De l'Electrisation Localisée, et de son Application à la Physiologie, à la Pathologie, et à la Thérapeutique."

This work became known to the profession in Germany through the abridged translation of Dr. Erdmann.

The leading idea of the method of localized faradization of Duchenne was, that the current can be localized over a fixed point under the skin if well-moistened conductors are strongly pressed upon the skin.

He observed—what is perfectly familiar to all experimenters in electro-therapeutics—that when dry electrodes are applied to the dry skin, sparks with a crackling sound are produced, but no sensation and no muscular contraction. He observed that when the electrodes are well moistened, contractions are excited in the muscles, with the phenomena of sensation.

He recommended three forms of electrodes—solid metallic electrodes, metallic brushes, and the hand.

On these observations and experiments Duchenne based a system of electro-therapeutics and electro-diagnosis which, as since refined, devel-

* In Pike's "Catalogue of Mathematical, Optical, and Philosophical Instruments," 1848, there is a cut of the faradic apparatus that had been in use for five years by these early experimenters. The same work also contains a cut illustrating their method of localized faradization of the leg.

oped, and modified by himself and by numerous other laborers in various countries, has now grown into a permanent department of science.

Localized faradization was appreciated by electro-therapeutists more rapidly than some of the other methods of using electricity, as electrolization, general faradization, galvano-cautery, and central galvanization, for the reason that it is the easiest learned of all the methods and requires only the simplest and cheapest form of battery. To be an expert in it requires a degree of skill and experience and manual facility, as well as familiarity with the diseases for which it is indicated, and some knowledge of electro-physics and electro-physiology are of essential service; but in none of these respects is this method as exacting as any one of the others.

Hence it is that localized faradization is the method with which novices usually begin their experiments in this branch, and it is the method which by the mass of the profession is now more used than any other.

Among specialists, however, of all countries, localized galvanization is more used than localized faradization, since it meets on the whole, as experience shows, a larger range of indications.

History of Localized Galvanization.—One of the ablest and most prominent of those whom the writings of Duchenne inspired to enter upon the study of electro-therapeutics was Professor Remak, of Berlin. His first work, "Ueber Methodische Electrisirung Gelähmter Muskeln," "On the Methodical Electrization of Paralyzed Muscles," was published in 1855. In this work he revived and recalled the attention of the profession to the galvanic current, and he furthermore announced that in order to bring a muscle to complete contraction it is better to excite its motor nerves than to allow the current to operate on the muscular substance itself. His second work, "Galvano-Therapie der Nerven- und Muskel-Krankheiten," was published in 1858.

Remak became the founder of a school of electro-therapeutists in Germany, as Duchenne had been in France. Their systems, as has been said, differed in two important particulars: both used localized electrization. Duchenne used the faradic current, making the applications to the muscles; Remak used the galvanic current, making the applications to the motor nerves.

Duchenne declared that the galvanic current was useless for the treatment of disease, while Remak contended that it was the only current that was of any value. Duchenne was unwilling to admit the reality of the discoveries of Remak, and Remak as emphatically rejected the conclusions of Duchenne. Both enforced their statements by the results of experiments, and both appealed to experience.

It is now well recognized by all electro-therapeutists that there was truth on both sides of this interesting controversy—that the galvanic and faradic currents are both of service in the diagnosis and treatment of disease, and that too in more than one mode of application. We now see that if Duchenne was too dogmatic, Remak was too extravagant, but that both of them, by their experiments and labors, were of positive service to science, and made the way easier and safer for those who have since followed them in the department of localized electrization.

Remak, shortly before his death, published a work entitled "Application du Courant constant au Traitement des Névroses," Paris, 1865, which contained the leading ideas of his system, and has been the means of stimulating many other experimenters in this difficult department.

Remak did more than merely introduce the galvanic current to the profession—he discovered and recommended special applications of the current, and suggested the theory of its catalytic action. He was the first to scientifically investigate localized galvanization of the cervical sympathetic, of the brain and spinal cord, and thereby greatly widened the sphere of electro-therapeutics. Although at first his theories were scouted and his statements discredited, yet since his death they have, in the main, been strikingly confirmed, and are now regarded as accepted facts in science.

Even during this last era, franklinic electricity has been by no means laid aside. In 1847 Dr. Golding Bird published very remarkable results obtained in the treatment of amenorrhœa by static electricity, in Guy's Hospital. He made use of a Leyden jar. Franklinic electricity has been successfully used by Drs. Gull and Clement. It has, for a number of years, been successfully employed by Dr. Radcliffe and others, in the London Hospital for the Paralyzed and Epileptic. Quite recently Professor Schwanda, of Vienna, has reported suggestive results from franklinic electricity generated by Holtz's electrophorus machine. Dr. Arthius, of Paris, published a work on the subject, and with improved apparatus the results have been better and its literature increasingly abundant.

Localized faradization and galvanization has been developed and improved in France, in Germany, in England and America, by a number of able and laborious men of science. Among the voluminous authors who wrote prior to the more recent developments in this department may be mentioned the names of Meyer,* Becquerel,† Baierlacher,‡ Althaus,§ Tripier,‖

* "Die Electricität in ihrer Anwendung auf praktische Medicin," Berlin, 1854 and 1868, Translated by Dr. Hammond.

† "Traité des applications de l'electricité à la Thérapeutque," Paris, 1857.

‡ "Die Inductions-Electricität in physiologisch-therapeutischer Beziehung," Nürnberg, 1857.

§ "Treatise on Medical Electricity," London, 1859. Latest edition, 1873. "Galvanism in Paralysis, Neuralgia, etc.," 1866.

‖ "Manuel d'Electrothérapie," Paris, 1861.

Rosenthal,* Frommhold,† Ziemssen,‡ Garratt,§ Benedikt,‖ Brenner,¶ Cyon.**

History of General Faradization.—In general faradization the aim is to bring the whole body under the influence of the faradic current, so far as is possible, by external application.

The origin of general faradization, like that of localized, is somewhat uncertain, since it is difficult to determine how long it was used by the laity before we formally introduced it to the profession. It is certain that both methods have been in popular, and, to a certain extent, in professional use in America, from a period not long subsequent to the popularization of the discovery of induction, certainly a long time before they were introduced to the profession. One of the first—and probably the very first—to employ a form of general faradization was William Miller, of New York, who began the empirical use of this system of treatment in 1843. Since that time some form of general faradization has been employed by Sherwood, of New York; Dr. W. Demming, of Portland; Drs. Garratt, Cross, and Guthrie, of Boston; Dr. Wells, of Rochester, N. Y.; Drs. Page and Channing, and by a very large number, both in the profession and out of it, of whose names and special methods but little is known, since they have taken but little pains to establish the treatment on a scientific basis, or to introduce it to the attention of the profession. Many of these practitioners combined localized with general faradization, and some, perhaps the majority, employed the latter exclusively, though with little definiteness or precision. Although, as has been said, some of these early experimenters were educated physicians, the majority were ignorant not only of medicine, but of every other department, and not a few, unfortunately, were as unprincipled as they were ignorant.

Although many of these experimenters were laymen, although they had no part nor lot in the realm of science, and although many of them were as devoid of conscience as of intellect, yet we should none the less eagerly seek for and accept whatever of truth they may have stumbled upon or discovered. In the history of therapeutics it has often been the fortune of the ignorant and the lowly to hit by chance on some great fact for which the wisdom of the ages has sought in vain. Says Dr. Stillé, "Nearly every medicine has become a popular remedy before being

* "Die Electrotherapie, ihre Begründung und Anwendung in der Medizin," Wien, 1865. Latest edition, 1873.

† "Electrotherapie mit besonderer Rücksicht auf Nerven-Krankheiten; vom praktischen Standpunkte skizzirt," Pesth, 1865.

‡ "Die Electricität in der Medicin," Berlin, 1866. Latest edition, 1872.

§ "Medical Electricity," Philadelphia, 1866.

‖ "Electrothérapie," Wien, 1868. Second edition, 1874.

¶ "Untersuchungen und Beobachtungen auf dem Gebiete der Elektrotherapie," Leipzig, 1868 und 1869.

** Principes d'Electrothérapie," Paris, 1873.

adopted or even tried by physicians;" * and according to Pereira, nux vomica is one of the few remedies the discovery of which is not the effect of mere chance.†

Impartial history must, we think, record that, before Duchenne and Remak were known on either side of the Atlantic, before our more recent electro-therapeutists had commenced their professional labors or studies, there were in this land not a few empirics who, by some form of general or localized faradization, or both combined, or by methods various and inconsistent, and in spite of their own ignorance or vice, were achieving successes in the treatment of disease which, in certain features, even the most advanced physicians of our day have not yet surpassed. If they did not belong to the chosen ranks of the profession, it is none the less true that the results which they secured were oftentimes such as the ablest leaders in science might well have envied. If their methods were empirical, their empiricism was often justified by its success. If their nomenclature was imperfect and confused, and their diagnosis erroneous, yet their confusion and errors were not a little redeemed by the skill with which they met emergencies when the therapeutist was far more needed than the pathologist or the diagnostician. The great defect of these empirics was not in their results, which oftentimes were truly remarkable, but in the fact that their general ignorance, and especially their ignorance of medicine, rendered it impossible for them to discriminate in their cases or their methods, or to intelligently communicate their experience to others, or in any way to make it of permanent value to science. They treated all cases about alike, without reference to the pathological condition, and in spite of all their successes frequently failed where, with better knowledge, they might have succeeded.

In Europe, so far as we can ascertain from the published writings on the subject, or from our own personal observation, the method of general faradization, as described in this work, had not been used or recommended, at least by men of science. In 1852 Beckensteiner ‡ suggested the idea of "animalizing" static electricity by passing it through the body of the operator, and making passes over or near the patient.

In 1857 M. Dropsy § de Cracow published a new method of faradization, the *modus operandi* of which consisted in connecting an electrode by two branches on the top of the head and the epigastrium, while the other electrode was connected by four branches with the hands and feet. At

* "Therapeutics," vol. i., p. 31. The same author states that "by far the greater number of [medicines] were first employed in countries which were and are now in a state of scientific ignorance."

† "Materia Medica," vol. ii., p. 336. Hydrate of chloral may now be added to this list.

‡ "Études sur l'Electricité," Paris, 1859.

§ "Electrothérapie en application médicale pratique de l'électricité basée sur de nouveaux procédés," Paris, 1857, in 8vo.

each sitting the poles were reversed. In 1858 Seiler * proposed to cure consumption and many other obstinate and incurable diseases by passing a faradic current through two electrodes near to but not over the body of the patient.

In 1863 Gubler † suggested the treatment of conditions of debility by placing both hands and feet in separate basins containing salt water, and passing a faradic current through the body.

Our own attention was called to the subject of general faradization in 1867, and in that and the following year we introduced it to the profession, describing in a general way its powerful tonic effects and *modus operandi.* ‡

The name general electrization, as descriptive of this method of treatment, was first employed by us and in the writings to which we have referred. In the present edition of this treatise we restrict the terms to general faradization, for the reason that our method of central galvanization, to be hereafter described, has to a considerable extent taken the place of general galvanization.

Our own claims in regard to general faradization are:

1st. To have studied the method as practised by the laity, and to have improved it, reduced it to a system, and given it a scientific basis, and to have shown its relations to other methods of using electricity—in short, to have done for this method what Duchenne did for localized faradization.

2d. To have interpreted its special and general effects, giving it a name, pointing out the true rationale of the method, and the indications for its use.

3d. To have first called the attention of the profession to this method, enforcing our views by the results of personal experiments.

4th. To have discovered in our experiments with this method that electrization distinctly aided nutrition, was a tonic of great and varied efficacy, and therefore indicated in a large range of conditions of debility, and to have forced this fact on the professional mind until it has become widely accepted, and has become the basis for the use of electricity in the treatment of medical diseases.

The length of time required to make a thorough application of general faradization, and the amount of practice necessary to acquire skill and facility in its employment, have interfered somewhat with its popularization among specialists in electro-therapeutics; but in spite of these difficulties the method is now used with the highest success by hundreds of physicians, specialists, and general practitioners.

* "Galvanisation par influence," Paris, 1858.

† "De l'Electrization générale," Bulletin de Thérapeutique, December, 1863.

‡ "The Medical Use of Electricity, with special reference to General Electrization as a Tonic, etc." Beard and Rockwell, New York, 1867.

In Germany the method has been from the first received, in part through the careful résumé of Professor Erb, of Heidelberg, with greater interest and appreciation and with more favorable consideration than in any other country, excepting perhaps the United States. Dr. R. Väter, of the University of Prague, in his preface to the German translation of the first edition of this work, has warmly recommended the method, basing his recommendation on his own personal experience; and Benedikt of Vienna, in the latest edition of his work, and others have given the method intelligent and appreciative consideration.

History of Central Galvanization.—The method of central galvanization, as has been described in our published papers " (Electricity and the Sphygmograph," New York *Medical Record*, December 15th, 1871; also "Recent Researches in Electro-Therapeutics," October, 1872, by Dr. Beard; "Central Galvanization," New York *Medical Journal*, May, 1872, by Dr. Rockwell), consisted in placing the negative pole at the epigastrium, while the positive was applied over certain portions of the head. over the sympathetic and pneumogastric in the neck, and down the whole length of the spine from the first to the last vertebra. At that time we had used the method with the highest success in hysteria, insanity, neurasthenia, gastralgia, dyspepsia, and certain diseases of the skin, and since that time this method has been extended to a wide variety of affections. In some diseases it has supplemented, in others it has supplanted, general faradization and galvanization of the cervical sympathetic.

The names of some of the more recent investigators in the realm of medical electricity have either already been mentioned in the previous chapters of this work, or will appear in the section devoted to practical electro-therapeutics in connection with the work they have done.

CHAPTER II.

GENERAL THERAPEUTIC ACTION OF ELECTRICITY.

Electricity in its Medical Relations is a Stimulating Sedative Tonic.— The cause of medical electricity has been, and still is, greatly retarded by vague and incorrect notions of the position of electricity in the materia medica. It has been classed as a stimulant, and up to the time when we began to write on the subject, nearly all the writers on the subject had assumed without question or discussion that the stimulating action was the main if not the only action of electricity. The idea that it was also a tonic in the sense of aiding nutrition was not even discussed. The first formal presentation of the use of electricity by the method of general faradization appeared in our paper, based on considerable experience and many experiments, and entitled "Electricity in the Treatment of Rheumatic Affections," and published in the *Medical Record.* In this and subsequent papers the nutritive effects of electricity were fully demonstrated. Those few in the profession who used electricity at all had gone no further than Duchenne, and supposed that when they had used this agent to prick up palsied muscles they had exhausted its therapeutic indications. In obedience to the same narrow and exclusive dogma, electricity was supposed to be exclusively contraindicated in febrile and inflammatory affections, and was supposed to be of value only in a very limited range of subacute and chronic diseases. The acceptance of the view that electricity powerfully influences nutrition has wrought a revolution in electro-therapeutics. An agent which was formerly used mainly if not exclusively in paralysis and rheumatism is now used, and with far more brilliant success, in hysteria and affections allied to it, in anæmia, neurasthenia, in nervous dyspepsia, neuralgia, chorea, in the convalescence from fevers, in many forms of pain and debility, and even in some cases of insanity.

It is necessary to state, at the outset, that in classing electricity as a stimulating sedative tonic, we use the words in the sense in which they are ordinarily understood and employed when applied to other remedies and systems of treatment, and without any reference to the mere verbal distinctions that may be or have been made in the classification of materia medica. And yet the derivation of the term from the Greek τείνω, "I stretch," and from still another word τονόω, "I brace or give vigor," is sufficiently suggestive. We speak of toning a violin, so that its strings give forth a clearer and better sound. We do this by making them more tense. By this figurative allusion our treatises on materia medica and therapeutics describe tonic medicines as those which gradually produce the requisite degree of tension of the nervous system and of the living fibre generally, and which enable it fitly to respond to all of its natural and appropriate stimuli. The idea of tension is inseparably connected with all our notions of vital force, because the most common, if not the only conception we possess of organic power is derived from our experience of the phenomena of muscular force, which is always displayed in connection with the tension of muscular fibre.*

Stimulants are usually understood to be those agents which quickly excite the system, and temporarily arouse its activity. They are like the goad, which forces the exhausted beast to draw the burden, but does nothing to increase his strength; or like the blast of the furnace, which increases the combustion, but adds no fuel. We do not accept this definition, but would prefer to regard stimulants as those agents that correct, intensify, or economize the forces of the system.

Sedatives may be severally defined as those agents that allay irritability and pain and induce natural repose.

Tonics are ordinarily understood to be those agents which gradually improve nutrition, restore enfeebled functions, invigorate the system, and permanently increase its capacity for labor.

It is because electrization is capable of producing at once the effects which are ascribed to all these classes of agents that we have defined it a stimulating sedative tonic.

These various effects are not always mathematically distinct, but run into each other. The stimulant effect may at once lead to sedation, and the permanent improvement to nutrition follows after a long time, and is in part a result of both stimulation and sedation.

Of these three orders of effects, stimulation, sedation, and improvement in nutrition, stimulation is the one that is of the least importance, and yet it is the one that first strikes the observation, and the one which until very recently has been regarded as the exclusive test for the use of electricity in medicine. If electricity were merely a stimulant it would scarcely pay to use it in the treatment of disease, for its range would be so narrow, and the result of its use even in that narrow range so temporary and unsatisfactory, that physicians would not find it to their advantage to spend time and labor in making the applications.

The ill success of all previous attempts to popularize electro-therapeutics is to be explained in part by the fact that those who experimented with it looked upon it as a simple stimulant and nothing more, and recommended it accordingly. If it depended on its stimulating action only, the cause of electro-therapeutics would have little vitality. The

* Stillé: "Therapeutics and Materia Medica."

reason why electricity is now growing in popularity in the profession is because it is found to relieve all forms of pain, and to add tone to the system and improve nutrition after ordinary sedatives or tonics have failed.

Tonic Effects of Electricity Best Elicited by General Faradization, Franklinization, and Central Galvanization.—Reasoning from analogy, as well as from experience, it would seem that the full effects of electricity on the human body could only be obtained by making the applications all over the person and on the central nervous system in such a way as to affect the whole system. The influence of any drug or remedial agent on the constitution can only be ascertained by bringing the whole system under that influence. A man who habitually washes one of his fingers in cold water appreciates the tonic effects of the cold only in that finger; but a man who habitually takes a shower bath, or plunges into a tub of cold water, realizes powerful tonic effects on his entire system. If a man daily exposes one arm to the sunlight, while the rest of the body is enclosed in a dark cell, he receives direct tonic effects only in the exposed member; but he who walks forth and exposes his whole person to the solar rays will in time experience the full tonic effect of sunlight on his system. If one hand or one foot is vigorously and regularly exercised, the muscles of that limb exhibit the tonic effects of the exercise, and increase in hardness and perhaps in size; but if all the portions of the body are vigorously and regularly exercised, all the principal muscles will increase in firmness and perhaps in size, and tonic effects will be appreciated by the entire system.

Just so with all other tonic remedies and influences. If quinine, strychnine, iron, arsenic, oil, etc., could be localized in a single limb, only that limb would be directly influenced by them. Their tonic effect is only obtained by administering them in such a way that they will penetrate every portion of the body.

Electricity is no exception to this law. In order to ascertain its full effects on the system at large, and to determine its position among remedies, the applications must be made in such a way that the whole system shall, so far as possible, be directly or indirectly brought under its influence. This is best accomplished by the methods of general faradization, central galvanization, and the various methods of franklinization that are hereafter to be explained in detail.

In making a detailed comparison, therefore, between the effects of electrization and the effects of recognized tonics—quinine, iron, strychnine, physical exercise, sunlight, cold bathing, etc.—it is logically necessary that the applications should be so given that the whole body should be brought under the direct influence of the current, just as it is brought under the influence of other recognized tonics as ordinarily administered.

The immediate effects of an application of general faradization, central galvanization, or static electricity, are often a feeling of enlivenment and exhilaration, drowsiness, temporary relief of pain, and increased warmth of the body. The same effects are notably observed after the shower bath, a tumble in the surf, a brisk walk in the open air, or from the administration of alcohol.

Like other stimulating tonics, general faradization, central galvanization, and franklinization, when given in an overdose or in too great strength for the constitution of the patient or the condition of the system at the time, may be followed by secondary or reactive effects that are both disagreeable and positively alarming. The second or third day after an injudicious application, very sensitive patients, especially at the outset of treatment, may experience soreness in the muscles, an indefinable feeling of nervous exhaustion, irregularity of pulse, and sometimes exacerbation of special symptoms. It is well known that severe physical exercise will produce all these unpleasant secondary effects, especially in patients who are feeble and unaccustomed to muscular exertion. A cold bath, either in the surf or at home, that is too prolonged may give rise to all these symptoms the night or day following. Unpleasant effects may secondarily follow an overdose of our ordinary stimulants, as alcohol, or from internal tonics, as iron, quinine, strychnine.

The permanent effects of these general methods of treatment are as closely analogous to those which come from other tonic remedies and systems of treatment as are the immediate and secondary effects.

The very marked permanent effect of general faradization, central galvanization, and general franklinization is improvement in the sleep. Physical exercise—walking, boating, gymnastics, bowling—cold bathing, and the ordinary internal tonics do the same, though not so markedly and with far less uniformity.

These methods also permanently improve the appetite and digestive capacity, and regulate the bowels. Improvement in the various operations of digestion is one of the most uniform effects of our ordinary tonics, and it is for that purpose, more perhaps than for any other, that they are employed.

Like other tonics, general faradization and central galvanization equalize the circulation. This effect, when it immediately follows an application, is merely the temporary excitement, similar to what follows a rapid walk, or gymnastics, or alcoholic stimulants, and soon passes away. But when it becomes a permanent condition—when the patient feels less annoyance from chilliness and cold extremities—it is a resultant of the improvement in nutrition.

Like other tonic measures—gymnastics, active games, and outdoor amusements, etc., etc.—general faradization, central galvanization, and franklinization cause the muscles to develop in size and hardness, and sometimes, though by no means uniformly, produce important and rapid increase in the weight of the body, the result of the improvement in nutrition. Increase in weight is familiarly observed after a trip of pleasure, a vacation in the country, a voyage by sea, and very frequently indeed from the use of cod-liver oil and strychnine. General faradization sometimes causes the patient to increase in weight from the very outset of the treatment, and to an extent that is most surprising.

Like other tonics, these electric tonics, in their ultimate effects, increase the disposition and the capacity for labor of the brain or of the muscles. This is indeed the chief end to which all tonic treatment is directed, inasmuch as diminished capacity for labor is perhaps the condition for which tonics are most frequently advised, and it does not usually increase the capacity for toil until it has first improved the sleep, the appetite, the digestion. The same is true of many other, if not all, tonic remedies.

Experience shows that the general methods of electric treatment are usually contraindicated in those diseases and for those temperaments that will not bear any of the internal tonics. We find almost invariably that they must be used most cautiously, and meet with their worst failures in cases where quinine, strychnine, iron, and stimulants have proved to be injurious.

Whatever difference of opinion there may be concerning the rationale of electrization, or whatever dispute there may be concerning the use and the meaning of the words stimulant, sedative, and tonic, the majority of advanced practical electro-therapeutists must substantially indorse the emphatic words of Professor Niemeyer: "In the constant current we have a means more powerful than any other of modifying the nutritive conditions of parts that are deeply situated." *

Rationale of Electrization.—The stimulating, the sedative, and the tonic effects of electrization are resultants of the various and diverse action of the currents on the tissues. These effects have been defined as mechanic, physical, catalytic (increase of circulation and absorption), electrotonic (modification of nerve), electrolytic (electro-chemical decomposition), and chemic. The mechanic effects are more markedly observed from the faradic current, the other effects from the galvanic. These terms, considered as explanations of the action of electrization, are, it must be admitted, quite unsatisfactory, since they are incapable of exact and complete definition, and must, to a certain extent, include each other. It is safe to say that we know as much of the rationale of electrization as of most of our internal remedies. (See chapter on the subject in Electro-Physiology.)

Is Electricity Transformed into Nerve Force?—Nearly all of the earlier experimenters in electro-therapeutics assumed without argument that electricity was identical with the nerve force, or, at least, that it was directly transformed into it. Although the weight of evidence is at present decidedly against the theory of the identity of those forces (see Experiments

* "Text-Book of Practical Medicine." Translation of Drs. Humphreys and Hackley, vol. ii., p. 90.

of Helmholtz), yet the assumption that they are identical or can be directly transformed into each other, still lingers. The taking phrase, "Electricity is Life," is constantly used as the war-cry of rival instrument makers, and as the motto of travelling charlatans, on the street corners and at country fairs. Whatever future science may unfold, we are now forced to say that not only is there no evidence that electricity is identical with life, but also that the theory that electricity, when applied to the body, is ever directly transformed into nerve force has few if any facts or arguments in its favor. That the body can be charged with electricity, and that the normal electricity of the body can be changed in character, is clear enough; but it does not follow that such changing of electric condition has any direct influence on the quantity or quality of the nervous force. Whether galvanic or faradic electricity charge the body to any extent in passing through it may rightly be doubted; if they leave more electricity in the body than they found in it, it must be by virtue of the direct influence of the current over the nutrition. Electricity is no more life than light and heat are life. Like light and heat it may sustain life, not by direct transformation, but indirectly through its influence over nutrition. When the light of the sun falls on a plant or animal, when artificial heat is applied to a cold and paralyzed limb, growth is stimulated and nutrition improved, but not, so far as can yet be demonstrated, by any direct transformation of light or heat into nervous force. Similarly, also, we have no sufficient evidence as yet that the varied and marvellous improvement in nutrition that follows electrization is the result of anything more than the indirect improvement in nervous force, which is a part and result of the general improvement in nutrition.

In the time and manner of their development the tonic effects of general faradization and central galvanization resemble those of other tonics in these two particulars:

1. They are Developed Slowly.—This slowness of development marks a radical distinction between tonics and mere stimulants. The agreeable stimulating effects which immediately follow an application of electricity, just as they follow the use of gymnastics, walking, active games, etc., soon pass off or merge into the permanent or tonic effects that come more or less slowly, and after repeated treatment.

2. They are often Developed long after the Treatment is Abandoned.—Weeks and months after a patient has taken a course of general treatment by general and central electrization he may continue to improve in his general condition, even though very little progress may have been made while the applications were being received. Just so the tonic effects of a trip by land, of a sea voyage, of our ordinary summer vacations, are sometimes not appreciated until after we have returned home, and are again fully at work.

Why Were Not the Tonic Effects of Electricity sooner Discovered?—The inquiry now very naturally arises, why it is that the important fundamental fact—that electrization is a powerful means of improving nutrition, and capable of producing effects on the constitution similar to those which are familiarly obtained from the tonics in every-day use—has escaped the observation of the very able writers who in different lands have devoted themselves to electro-therapeutics, until we called attention to them?

The inquiry is thus answered:

1. Because most of the recent scientific observers whose writings are authorities in electro-therapeutics have used electricity locally, in some form of "localized electrization."

For obvious reasons, that have already been presented, localized electrization must produce chiefly local effects, which although they are tonic in their character, so far as they go, and reveal themselves by marked improvement in the local nutrition, would not ordinarily suggest the powerful constitutional tonic powers of which electrization is capable when applied all over the body, any more than the feeble effects of washing the hands, the face, or the feet, or any single member or organ, would suggest or give any intimation of the well-known constitutional effects of surf-bathing or the shower bath.

Indirect constitutional effects result from localized electrization of the central nervous system, and especially from galvanization of the brain, spine, and cervical sympathetic, although, as will be seen, they are not as marked as those which follow general faradization and central galvanization.

It is a very interesting and significant fact, however, that since the introduction into medical practice of the methods of localizing the galvanic current in the nervous centres first suggested by Remak, electro-therapeutists have achieved success in a variety of diseases associated with debility and impaired nutrition, where before electric treatment was supposed not to be indicated, at least by those who confined themselves to localized electrization.* A suggestive fact relating to this subject is that Gubler, who was one of the very few European writers who had used faradization in such a way as to directly affect the whole system, also remarked tonic effects in conditions of debility, even from his very awkward and imperfect method.†

2. Because the immediate effects of electrization are so markedly stimulating as to suggest the idea that it is simply and only a stimulant or irritant. In some of the cases for which localized electrization are used the stimulant are the effects which are chiefly desired. But, as has already been shown, many of our ordinary tonics are primarily stimulating, and so much so that they have been classed as stimulating tonics.

* *Vide* the writings of Remak, Meyer, Benedikt, Niemeyer.

† "De' l'Electrization génèrale considereé comme agent tonique et stimulant diffusible." Bulletin de Thérapeutique, Decembre, 1863.

There is little question that if many tonics in ordinary use had been used only locally, as electricity has been used, they might have been regarded merely as stimulants.

3. Because until quite recently most of the recognized authorities and writers on electro-therapeutics of modern days have not used electricity in those diseases and morbid conditions where tonics, *par excellence*, were demanded. They have used the agent mainly with a view to stimulating effects, and in some form of localized electrization. On this principle they have treated paralysis, rheumatism, neuralgia, etc. As we shall demonstrate hereafter, besides those diseases in which the efficacy of localized electrization is fully established, the morbid conditions and symptoms for which electrization is most rapidly and permanently successful are precisely those in which we use our ordinary tonics—such as dyspepsia, nervous exhaustion, insomnia, hypochondriasis, hysteria, general neuralgia, chorea, spinal irritation, and some forms of paralysis dependent on or associated with general debility.

Furthermore, in prosecuting this inquiry we must not overlook two important historical facts:

1. In the latter part of the last and early part of the present century franklinic electricity and the current of the voltaic pile were used for a variety of diseases for which we now use tonics, and oftentimes with some success. But the agent was used mostly empirically, without any definite idea of its nature or the *rationale* of its operation. Partly on account of the inconstancy and uncertainty of the voltaic pile, and partly on account of the many failures that were necessarily inevitable with such poor apparatus and desultory experience, partly also as a reaction from the extravagant hopes and promises of the earlier experimenters, this system of treatment soon fell into temporary disrepute.

2. Tonic effects have been obtained from various methods of employing electricity by non-professional men—charlatans and outsiders—in the United States at least, for many years, although very few of them have known or suspected the nature of the agent they dealt with, or of the diseases they have treated.

CHAPTER III.

GENERAL SUGGESTIONS IN REGARD TO THE USE OF ELECTRICITY AS A THERAPEUTIC AGENT.

Before describing in detail the different methods of using electricity, it may be well to offer some suggestions of a general character that will apply to all the different methods of electrization. It is of the first importance that those who are beginning to study and practise electro-therapeutics should have correct notions not only of the general therapeutic action of electricity—the principle on which it is used—but, also, of the general laws of its application. Such knowledge fits one to intelligently study the special methods of application, and the treatment of the various diseases. A want of this knowledge is a constant hindrance, and not unfrequently utterly discourages the beginner in this science.

General Indications for the Medical Use of Electricity.—An error that appears prominently in some of the works on medical electricity, and one that seriously interferes with the progress of healthy and philosophic electro-therapeutics, is the habit of treating the name of the disease rather than the condition of the system of which the symptoms are the result and expression. Men ask whether electricity is good for this disease or that disease without any well-defined idea of the position that this powerful agent occupies in the armory of therapeutics. It should be understood that electricity is a powerful stimulating sedative tonic, and as such is indicated in any subacute or chronic disease, where stimulating, sedative, or tonic effects are indicated, and without reference to the name of the disease by which the condition expresses itself. With this general principle before us, we cease to wonder that electricity is used and recommended in such a wide variety of diseases, many of them of an apparently opposite character, and we see the injustice of that criticism which condemns electricity because it is good for so many different affections. Just as quinine, which is not a specific for any disease—unless it be chills and fever—is yet used freely as a tonic in an indefinite number of diseases where tonic effects are required, so electricity, which is not a specific for any one disease, is yet used with good results in any number of diseases where local or general nutrition is impaired and needs to be improved. When the propriety of using electricity in any medical case is discussed, the first questions to be answered are:

1. Is there any pain to be relieved?

2. Is there any need and chance for improvement in local or general nutrition?

If these questions can be answered in the affirmative, then electricity in some mode of application may be administered. The result of the treatment will depend on the correctness with which we differentiate in the selection of the form of electricity, on the skill with which it is conducted, on the nature of the lesion and length of time that it has existed, and on the agreement or disagreement of the temperament of the patient with electricity.

Stage of Disease when Electric Treatment is Indicated.—Electricity is indicated mainly for subacute and chronic diseases; at least the best results that come from the use of this remedy have thus far not been obtained in the acute stages of disease. And yet there is no question that in the acute stages of rheumatism faradization is of value, and there is reason to believe that future experiments will show that relief of pain, of sleeplessness, and of general nervousness—with perhaps permanent benefit—may be obtained in the active stages of febrile and inflammatory affections. The chief theoretical objection to the employment of electricity in acute diseases is the fact that the tonic effects of electric treatment require so much time that any disease that runs but a limited period will not be able to appreciate them. This objection does not, however, apply to the stimulating or sedative effects; these can be felt instantaneously or within a few hours after an application. Electricity is certainly one of the most potent of sedatives, and in very many acute affections sedatives are constantly indicated.

The old notion that electricity was merely a stimulant aided in forming in the professional mind another very gross error, that in active inflammations electricity is contraindicated. Experience proves every day that the sedative effects of electricity are exceedingly grateful in even the acute stages of sprains and diseased joints.

The dogma that in hemiplegia from cerebral effusion it is better to wait for several months until all the active irritation has subsided before beginning electric treatment—which error is yet maintained by many of the ablest writers on medical electricity—took its origin in the erroneous conception of the position of electricity in the materia medica.

It is difficult to conceive of any actively inflamed or febrile state where electricity, in the hands of one who knows how to use without abusing it, may not be used without injury even if it does no good.

Differential Action of the Poles.—This is a subject on which much has been thought and written, and concerning which opinions have been expressed with an absoluteness not justified by experience. Almost the first question that the beginner in electro-therapeutics asks is, "Which pole shall I use?" as though that were the fundamental problem to be solved.

Another question that is put in almost the same breath is, "Shall the current be ascending or descending?"

The difference of the physiologic action of the poles of the galvanic current, when applied to the body, is, as we have shown under electro-physiology, of a radical character. It has specially been shown that the anelectrotonic region at the positive pole is in a condition of diminished, while the catelectrotonic region near the negative pole is in a condition of increased irritability. Moreover, it is easy of demonstration that the negative pole of both currents is stronger than the positive, and this fact, as we have seen, enables us to distinguish the poles in cases of doubt, or when we do not understand the construction of the battery. Still further we have seen that on the nerves of special senses—notably on the optic and auditory nerves—the poles have a differential action of a specific and demonstrable character.

When now we leave physiology and enter into the complex realm of therapeutics, we find that it is usually better that irritable parts of the surface of the body should be treated mainly by the positive pole. This relative position of the electrodes is not usually departed from in general faradization and central galvanization, for the reason that the majority of cases that require these methods of treatment are abnormally irritable.

The negative pole, being more stimulating than the positive, is indicated when it is desired to cause contraction in a paralyzed muscle, and the difference between the poles in producing muscular contraction is chiefly a difference of degree only, since both poles cause contraction when placed on the body of a muscle or over its motor point, but with the same strength of current a more vigorous contraction will be produced by the negative than by the positive pole. The chemic action of the poles is more definitely understood and utilized in treatment by electrolysis and galvano-chemic cauterization.

Differential Action of the Ascending and Descending Currents.—Almost from the birth of electro-therapeutics constant effort has been made to differentiate between the therapeutic action of the two poles of the galvanic current and to come to some definite conclusion as to the effects of current direction. Investigations along this line have, however, been beset with so much difficulty, and the observations as to the effects of this or that pole, or this or that direction of current have been so varied and inharmonious, that no very definite or satisfactory conclusions have been reached.

So conflicting indeed have been the statements offered that it is now not uncommon to hear the remark that it makes not the slightest difference which pole or which direction of current is used. While every careful observer knows that such a remark is based upon careless observation and insufficient data, yet it has been so frequently and so confidently repeated as to carry with it a certain weight of authority. One great difficulty in the way of correctly differentiating between the effects of the two poles has been the failure to completely eliminate the action of one pole when desiring the effects only of the other.

We have seen a hyperæsthetic or painful part to which both electrodes have been applied fail to experience relief until the poles were widely separated, throwing the neutral point outside the diseased area, thus subjecting the painful part to the action solely of the anode or positive pole. In several cases of scirrhous cancer of the breast that have come under our observation, we invariably failed to relieve the pain when both poles were applied on the tumor or in close proximity to each other, but by applying one pole at some indifferent point on the lower extremity and the other to the tumor, the pain has, as a rule, been greatly alleviated. One patient was for months treated almost daily, with the result of keeping her in great measure free from pain and enabling her to dispense altogether with the use of morphine, which had before been a necessity. The notable point in some of these cases was the utter insufficiency of this agent to relieve the pain, although tested many times when the electrodes were applied in close proximity to each other. But no matter how widely we separate the two poles in the treatment of special parts, the fact remains that we cannot by the use of ordinary electrodes completely eliminate an undesirable polar effect.

In order to demonstrate the different effects of ascending and descending currents, and the way and degree in which they modify the physiologic action of the two poles, we have many times repeated the following interesting and suggestive experiments:

Experiment I.—A frog was chloroformed and an ascending current of ten milliamperes was then passed for five minutes through one of the hind limbs, by placing an ordinary electrode connected with the negative pole on the lumbar region, and a depolarizing electrode with a resistance greater than the limb and connected with the positive pole, on the foot. The influence of the positive pole being thus eliminated, the limb was brought wholly under the influence of the negative pole. The current in this case we shall accordingly designate as the ascending negative. The usual closing and opening contractions were observed in the limb, which remained quiescent during the passage of the current. On breaking the circuit, the irritability of the limb to electric stimulus was tested by the application of two minute metal electrodes to the muscles. It was found that the minimum strength of current capable of producing visible contractions in the muscles of the limb was one milliampere.

Experiment II.—Next, a descending current of the same strength (ten milliamperes) was passed through the other limb by placing the depolarizing electrode connected with the positive pole on the loins and an ordinary electrode, connected with the negative pole, on the foot. The limb was thus like the other brought wholly under the influence of the negative pole, the direction of the current, however, being reversed, and can be designated as "descending negative."

At the end of five minutes the current was broken, when, on testing the irritability of the muscles, it was found that a current of four milliamperes was required to excite contractions as against but a single milliampere in the case of the leg first tested. Similar results were obtained with the "ascending positive" and "descending positive" currents, the former diminishing the irritability of the muscles by one-third, while the latter diminished the irritability by two-thirds, or twice as much. From these experiments we may fairly conclude, first, that the direction of current *per se* (provided the action of one of the poles be eliminated) has an important influence on the irritability of muscular and nervous tissue; second, that the polar influences are greater than, though distinct from, those of direction. These conclusions are, we are aware, quite contrary to those enunciated by the earlier experimenters in electro-physiology. Erb says that "all proof is lacking that the direction of the current is an essential factor in its action;" but it must be remembered that the experiments from which Erb drew his deductions were performed long ago, before we had at command delicate instruments of precision for accurately measuring the strength of the current, and that he did not experiment by eliminating one of the poles as here described.

Physiologic experiment clearly demonstrates, through this method of accurate measurement, that it is not alone polar action, but current direction as well, that is important in electric applications, and clinical observation does but confirm these physiologic data. To determine the therapeutic value of the depolarizing method of treatment is a task requiring a keener analysis and more prolonged observation.*

Both the Seat of the Disease and the Effects of the Disease to be Treated.—The query whether in localized electrization we should direct the treatment mainly to the seat of the disease—the pathological lesion, or to the seat of the prominent symptoms—the effects of the lesion—has given rise to some discussion.

It sounds very practical to advise the treatment of the symptoms without regard to the seat of the lesion. It sounds very scientific to claim that the electricity should be confined to the exact seat of the disease. Now the wise physician is both scientific and practical, and keeping clearly before the mind this central thought, that the leading action of electricity is that of a stimulating tonic with a powerful sedative influence, we can readily discern the truth on this subject. Both the seat of the disease and the seat of the symptom should be treated, for in both there is need of improvement in nutrition. In this view common sense and experience accord. In hemiplegia, for a typical example, the lesion, the seat of the

* For a more detailed discussion of this subject reference is made to the author's articles in the New York Medical Record, May 14th, 1892, and May 6th, 1893.

disease, is in the brain, while the leading symptom is in one-half of the body, which is paralyzed. The muscles of that side become atrophied, and the nerves become anæsthetic. To restrict the electrization to the brain, and to that side of it where the lesion is or is supposed to be, is so imposing and scientific in theory that electro-therapeutists of limited experience might advise this treatment exclusively. To purify the stream, first purify the fountain. Lay the axe at the root of the tree. All these analogies are beautiful, but they are fallacious. The symptoms of the disease will not disappear when the disease disappears. The effects remain after the clot is absorbed. In the larger number the half of the body is as much the seat of the disease as the brain; for the several parts of this human machinery are all members one of another. When one suffers all suffer. To confine the treatment to the paralyzed muscles is also irrational, although the purely peripheral treatment is far more successful than purely central. If we are to be exclusive and one-sided and theoretical in our treatment, it is better to exclusively treat what are called the symptoms or effects of the disease, and to neglect the brain altogether. But it is the part of the higher wisdom to use both methods, central and peripheral—to attack the seat of the lesion and the seat of the symptom.

The most satisfactory results in hemiplegia come from a combination of peripheral and central treatment; similarly in the various degenerative structural diseases of the spinal cord, resulting in paralysis of motion or sensation. Purely central treatment—galvanization of the spinal cord—is not sufficient; the symptom also, the paralysis, must be treated directly in the muscles and nerves where it is most prominent. In diseases of the spinal cord, treatment confined to the seat of the disease does more good than in diseases of the brain, for the reason that the cord is more accessible to the current, its surface being more exposed, as it were, throughout its entire length. But those who content themselves with treating diseases of the cord by simple galvanization, to the exclusion of peripheral treatment, make a grave mistake; they fail where they ought to succeed, and they succeed only in a small percentage when a large percentage was possible. Cases of ataxia, as well as of motor paralysis, need peripheral treatment with the moist sponge or wire brush, or both, as well as galvanization of the spine. On the same principle our method of central galvanization is sometimes more effective in diseases of the cord and brain than localized galvanization of these parts, as usually practised. In neuralgia also where the seat of the disease is in the nerve centres, the application should be made both to the tender and painful points, as well as over the root of the nerve, and a very good method of application is to place one pole over the origin of the painful nerve, as near as possible, and the other over the tender point and along the whole course of the nerve. Frequently neuralgia, as we shall see, yields to our method of central galvanization—where not only the painful and diseased parts, but also the whole central nervous system, whether healthy or not, is treated, —when it does not yield, at least as rapidly or as surely, to local applications either central or peripheral.

Healthy Parts may be Benefited by Electrization.—There is a kind of unconscious idea abroad among electro-therapeutists that in applying electricity to the body it is necessary to avoid acting on healthy parts, and that the direct effects of the current should, so far as possible, be confined to the part that is supposed to be in a diseased condition. This erroneous doctrine takes its origin, first, in the teaching of Duchenne and other advocates of localized electrization, and, secondly, in the narrow and incorrect ideas of the general physiologic and therapeutic action of electricity.

Duchenne, by embodying the term "localized" in the title of his work, has done much to popularize in the profession the notion that in electric applications the aim should be to concentrate the current on the part where it is supposed to be needed, and to avoid affecting other parts.

The idea that electricity is a mere stimulus, and only valuable as a means of exciting paralyzed muscles or waking up dormant nerves, would very naturally lead to the adoption of the view that it should be used only in those parts that are in need of stimulation, and that healthy parts would be injured by it. The false ideas that have prevailed in regard to effect of stimuli, which we have elsewhere discussed, have tended to increase this absurd dread of applying electricity to healthy parts. A little common sense applied to this subject may perhaps help us to find the truth without great difficulty.

First of all, we must bear in mind always that the doctrine taught by the European writers, that electricity is a stimulus merely, is narrow and erroneous. Electricity, applied to the body, acts as a stimulating tonic with a powerful sedative influence. Then, again, stimulants are something more than mere goads or spurs; they correct and intensify the forces of the body, and may be useful and as necessary in conditions that we call healthy as in those that we call unhealthy. Stimulants, tonics, and sedatives are called for every day, and are every day employed by nearly every member of the human race, young or old, sick or well.

Still further, pathology is not so much a special and separate condition as a degree of the normal condition of health. No one can tell just where physiology ends and pathology begins. Reasoning from all these considerations, it is clear not only that electricity need not be confined to diseased parts, but that the parts that we call healthy may be benefited by it just as truly as those that we believe to be unhealthy, and the benefit they receive may react favorably on the diseased parts, and thus aid the treatment.

These views are enforced by analogy. Very few of our stimulating tonic or sedative remedies are limited in their action to parts that are diseased. The medicines that we give by the mouth or by the syringe go whither they please, and if they sensibly affect some diseased organ, it is not because their action is confined to that organ, but because that organ, on account of its readier operation or of its disease, is more sensitive than other parts to the influence of remedies. Alcohol or opium go to the brain, lead affects the exterior muscles of the forearm, and the influence of chlorate of potash is quickly felt in the mucous membrane of the mouth; but none of these remedies restrict themselves to the parts that are the most perceptibly affected by them.

Indeed, the fact that our most valued medicines are used for such a variety of local and general affections shows that their effects are not confined to separate parts of the body to the extent that has been supposed.

Electricity can be localized, in cases where it is desirable to do so, better than almost any other remedy, and yet the most careful and successful localization of the current is more or less imperfect. The reflex effects of electrization that always complicate the direct effects, and which are sometimes of more value than the direct effects, cannot be avoided. Then, again, the branch currents, which, as we have seen, move in undulations not only directly between the electrodes, but at a considerable distance on either side of the median line between them, will be likely, in nearly all forms of application, to touch healthy parts that do not stand in especial need of treatment. The most complete form of localized electrization is electrolysis when the needles are placed close together, but even here the reflex effect is most powerful, and operates with a mild as well as with a strong current.

But fortunately it is never necessary to localize electricity, in the strict sense of the term. It is sometimes necessary, however, to avoid producing too strong reflex effects, and in applications near sensitive parts the possibility that the branch currents, if powerful currents are used, may over-irritate, should ever be borne in mind. Experiment and experience show that healthy animals and men can be electrized with benefit all over the body, or in any part of it. In applying electricity to any part of the body we improve the nutrition of that part; in applying electricity to the whole body we improve the nutrition of the whole body, or, at least, of those parts which are directly or indirectly influenced by the current. Faradization of a healthy muscle makes it grow faster than it would grow without faradization; in other words, it produces the same effect that it would if the muscle were paralyzed. When a part is in a pathologic condition—when, for example, a muscle is atrophied—any improvement in nutrition under electrization is more quickly observed, and is probably more rapid and important than when the same muscle is treated in a physiologic condition; but the improvement of the healthy muscle is none the less real, though it may be relatively less important than in the diseased muscle.

The tonic effects of general faradization and of central galvanization, and, indeed, of many forms of localized electrization are due to the direct or indirect action of the current on parts which are more or less healthy, or which, to say the least, are not in any recognizable pathologic state. The objection sometimes brought against these methods, that they do thus affect healthy parts, simply attempts to prove too much. The same argument would banish all, or nearly all our stimulants, tonics, and sedatives from our materia medica, and practically discourage all attempts to relieve or cure chronic diseases of the nervous system.

Care in the Details of the Applications.—There is as much difference between a skilful and an awkward application of electricity as there is between a skilful and an awkward operation in surgery. By those who desire to become experts in applying electricity, the following points should be considered:

1. To avoid suddenly interrupting the currents in cases where interruptions are not required, and especially in applications on or near the head. In the treatment of paralysis of motion and of sensation, interruptions are required, but in the treatment of the brain, spinal cord, and sympathetic, and in very many peripheral applications stable currents only are required. In all such cases the current should be closed gradually and delicately, if possible by means of a rheostat of some kind, or by increasing or diminishing the pressure on the sponge of the electrode. Interruptions made in the metallic part of the current are always more sudden and violent than those made in the electrodes, for the physical reason that the connection of the current is more sharp and abrupt.

Delicate patients should be treated with delicacy. Those who are sensitive and apprehensive should never be annoyed by sudden breaks in the current, except in those forms of disease where sudden breaks are required.

In presenting this caution we do not intend to indorse the notion that serious pathologic lesions are caused by interrupting the current, even on or near the brain. There is little or no evidence besides the case of Duchenne, that any serious injury to the retina, or to the auditory nerve, or to any part of the brain, or sympathetic, or spinal cord, has been produced by faradization or galvanization with the strength of current ordinarily employed in electro-medical applications. The dizziness, the sour taste in the mouth, the flashes of light before the eyes, the shock or agitation produced by the sudden interruption of the galvanic current, are annoying, and to the delicate patient unaccustomed to them sometimes alarming; but with the batteries in ordinary use, and with the strength of current that is, or ought to be, employed through the head and neck, they are rarely if ever dangerous: they are temporary effects that soon pass away, and are forgotten. But they are to be avoided in cases where they are not required, for the threefold reason that they do no positive good, that they may interfere with the success of the treatment, and that they alarm or annoy the patient. We are to avoid worrying our patients in this way, for the same reason that we are to avoid treading on their corns, because it is disagreeable and discourteous.

2. To avoid making the applications unnecessarily painful through carelessness in the management of the electrodes. By the use of fine and soft sponge—the best that can be found in the shops—or, better still, of sculptor's clay, the smarting and stinging pain of the applications can be much diminished. Aside from the fact that, with some exceptions, less satisfactory results follow painful than pleasant currents, the feeling of pain should, so far as possible, be avoided. There are, as we have said, a certain number of patients who carry into medicine the same views that once dominated in religion, and who desire to suffer, and have very little respect for any treatment that does not cause more or less agony. Such patients will sometimes find, after one or two severe and painful applications, that they are injured more than benefited, and will submit to the advice of the physician and take the treatment that is best for them.

3. To avoid surprising and startling the patient by allowing the wires, or the metallic portions of the electrodes, to touch any part of his exposed body. If the connecting wires slip out of their connections with the electrodes they are liable to fall on the exposed skin and give a painful shock. If the edge of the electrode not covered with sponge or cloth touches the skin, it will give the patient sudden pain, and annoy both him and the operator. Connecting wires that are not protected by rubber are liable to lose their silk or cotton coverings in places, which when they touch the skin cause pain.

4. To be always and every moment sure that the current is running, and when the galvanic current is used to observe and carefully record the strength in milliamperes.

Disrobing of the Patient.—The great majority of electric applications with dynamic and occasionally with static electricity require, on the part of the patient, more or less loosening or removal of the dress. Not only is this necessary in general faradization and central galvanization, but in very many local applications to the spine, abdomen, and upper and lower limbs—excepting merely the face, head, and hands. To know how to direct the patients to arrange their clothing so as to give the operator sufficient and easy access to the person is a part of the art of practical electro-therapeutists, and it is an art not to be despised. Male patients have less trouble in this regard than female patients, since their garments are fewer and simpler, but they are more annoyed by the little they have to do than women are by their vast paraphernalia. The art consists in loosening and pulling up without entirely removing the underclothing, thus avoiding trouble, exposure, and waste of time.

Temperature of the Electrodes and of the Operating Room.—The question is often raised by patients whether there is any danger of taking cold after an application of electricity. The answer is clearly in the negative. The electricity, as such, so far as it goes, fortifies the system against cold; but, by careless exposure while undressed in a cold room, it is possible to take cold, just as by similar exposure when electricity is not used. It is also possible to make the application quite uncomfortable by using sponges moistened with cold instead of tepid water. Our aim should be to have the temperature of the operating and dressing-room a little higher than is necesssary for a person fully dressed; to moisten the sponges or electrode covers in tepid or—in very cold weather—in hot water; and when the feet are placed on a foot-plate of tin or copper, to have a warm soapstone beneath the foot-plate to keep it always comfortable.

Time of Day for the Application.—Applications of electricity may be given with advantage at all hours of the day and night. In our experience, and probably in the experience of all electro-therapeutists, the majority of the applications are given in ordinary business hours, in the forenoon and afternoon. We have never been able to see that anything was gained by giving any particular heed to the hours of eating; just before meals, and just after them, ordinary electric treatment may be given with apparently as much benefit as two or three hours from a meal. In some impressible temperaments, central galvanization and general faradization temporarily increase appetite, and for such persons an application might very properly be given a little before meals. For those who suffer from dyspepsia, a *séance* pretty soon after dinner might be of service in aiding digestion, but we cannot say that we have seen any such results.

For all delicate, hysterical, sleepless patients, the evening is an excellent time to receive electricity. The powerful sedative effects of central and general faradization and positive static electrification are in this class of patients most gratefully realized a little before going to bed, or after they have already retired. For these reasons we have, for years, been accustomed to treat some of our patients in the evening, before or shortly after retiring, and, were it not for the inconvenience, we should do it more frequently.

Time of Applications.—The time of an application is an element of the dose of electricity that has not been sufficiently studied. Electro-therapeutists have fallen into the conventional and routine habit of using the current all the way from five to ten or fifteen minutes or so, at a sitting, without sufficiently investigating the question whether the length of the application ought not to be varied with studious care, in each case, and varied during the course of treatment.

For irritable, sensitive, and impressible patients this law certainly holds: that long applications with mild currents are better than short applications with strong currents. We do not of course refer to electrolysis or galvano-chemic cauterization, which is so important a part of the electro-therapeutics of gynecology. Here the reverse law often prevails. The great difficulty in most cases is to concentrate a sufficient strength of current under the skin without unduly irritating the skin itself. Our constant aim should be to overcome this resistance with the least discomfort to the patient, and fortunately, by the use of clay electrodes which so readily adapt themselves to every inequality of surface, we are able to apply currents of far greater strength than formerly without disturbing our patient.

A sudden shock, or a series of shocks with a powerful current, may injure, where a prolonged application may work no harm and much good. That this element of time becomes a practical difficulty in the use of electricity by overworked general practitioners must be admitted: but if it be a scientific fact—as it surely is—that time is required to gain the choicest and best effects of electric treatment, then we must recognize and accept the fact, and treat our patients accordingly, and expect them to reward us for our labors more liberally than for a mere prescription or suggestion.

Frequency of the Applications.—Ordinary stimulating and tonic medicines are given one, two, and usually three times a day. The dose of electricity cannot usually be administered so frequently without doing more evil than good. It seems essential to the electro-therapeutic treatment, whatever the mode employed—general and local faradization, central and local galvanization, and even electric baths and the use of the body batteries —that there should be a considerable period of rest between the applications.

Electrization sets in motion forces that slowly act and react hours and days after the electrization has ceased. The time required for these forces to operate to the best advantage varies with individuals, but in all cases a certain period of rest is required, and if the application be repeated before this period or some portion of it has elapsed, the benefits of the previous application are more or less neutralized, and the patient may be weakened more than strengthened. This at least appears to be the conclusion that long experience forces upon us. All the way between every day or once a week the applications can be given with benefit. Three or four times a week is about as often as the average patient cares to make his visits, and it is safer to begin treatment with at least an interval of a day or two between sittings. Some patients require, at the outset of a course of treatment, intervals of three or four days. If by accident or intention strong and long applications are made, unpleasant reactive effects may follow that at once suggest the necessity of waiting for a day or two.

On the other hand, there are those who can take full applications every day for a month in succession, and in some cases, as it appears to us, with greater benefit than would be derived from applications given every other day. At the founding of the Electro-Therapeutic Department of Demilt Dispensary we received patients only twice a week, and good results were obtained under that system, but we afterward found it desirable to add another day.

General and central applications require longer intervals than local and peripheral applications, for the patent reason that they more powerfully affect the whole system, and are more frequently followed by reactive effects. Local applications indeed for the relief of pain often demand to be frequently repeated, and prolonged applications once every 24 hours are often imperatively demanded.

Chronic nervous diseases cannot be cured in a day; time is as necessary as the electricity. Long-standing pathologic lesions are not to be carried by assault, however bravely conducted; they yield only to a protracted siege.

Regularity of the Applications.—It is the custom with some electro-therapeutists to insist on regularity in the days and hours of the applications, and there are those who believe that the best effects follow regular and methodical treatment. On this point we are in some doubt. Patients who are methodical in their habits, and who are regular in their visits, will be less likely to omit visits, and will be more likely to persevere, and consequently will be more profited than those who omit half of their visits and abandon treatment before it is fully tried. There is no evidence that regularity, as such, is any advantage; although there is strong probability that for some constitutions, and, perhaps, for diseases with periodic symptoms, it might be an advantage to give the applications at the same hour daily, or every other day, as the case may be. Our own custom in this regard varies. Practically we find it impossible to treat all patients with absolute regularity, and in those cases where we are able to do so we have not, thus far, been able to see any special therapeutic advantage.

Prolonged Applications.—A method of using electricity that has been too little studied by the profession is that of prolonged applications with mild currents.

In certain diseases, both medical and surgical, it is of advantage to allow the current—galvanic or faradic—to run for several hours—all day or all night—as may be convenient.

We have become so accustomed to the use of short, or comparatively short applications, that we forget that the current if sufficiently gentle may be passed through the body, or part of the body for hours, if not days consecutively, without injury, and with great benefit, provided certain cautions are observed.

When the galvanic current is thus used, care must be taken not to allow the electrodes to remain too long in one spot, since they will cause a disagreeable though not serious ulceration of the skin, that may be some time in healing. In order to avoid this ulceration, it is well to change from time to time the position of the electrodes, so that they may not act too long on one spot.

The details of this method of using electricity must be varied with each case and the circumstances of the patient.

Intervals between the Courses of Treatment.—It is sometimes of service to suspend a course of treatment after it has been going on a number of weeks, and to allow an interval of one or more weeks, according to circumstances. It is sometimes observed that patients improve as much during the interval as during the treatment, and when the applications are renewed, they have greater force than at the close of the course of treatment. It is true of electricity, as of almost every other stimulant, tonic, sedative remedy, that after receiving it a certain time the system becomes so accustomed to it as to tolerate it, and then its full force is not appreciated. In cases where this toleration of electricity is observed, when the improvement halts, so to speak, a brief suspension of treatment may be indicated, and on renewing it, all the benefit at first realized may be repeated.

On the other hand, there are patients who seem to prosper best under steady, uninterrupted treatment.

Combination of Methods of Application.—Comparatively few diseases are to be treated solely by any one method of application; many of the purely local affections even yield better to electric procedure, when the applications are varied, than when one mode only is persistently used. All currents, galvanic, faradic, and static, may be tried in alternation or succession, and both the direct and indirect methods may be employed at the same sitting or at different sittings. In all diseases where the whole system is involved, the method of application may be yet more varied. In some diseases, as notably in those where central lesions are accompanied by peripheral injury and general exhaustion, as hemiplegia, ataxia, and so forth, all the methods of application may be used, including faradization with the wire brush. We observe not unfrequently that after one method of electrization has done all that it is capable of doing, after it seems to have lost its power, another method of electrization, or a mere modification of a method, may push the improvement yet further, until it in time loses its force and the fresh stimulus of another method is required.

In this respect the behavior of electricity is in no way peculiar; to all powerful remedies the system in time becomes so accustomed, as to tolerate them without appreciating their remedial influence. In the administration of tonics in cases of debility, and of astringents in cases of chronic diarrhœa, a necessity for frequent change of remedy is generally recognized.

How to Judge of the Effects of Electric Treatment.—It is of the first importance for the electro-therapeutist to have a clear, just, and systematic method of determining the effects of electricity, both good and evil. Much of the difference of opinion that prevails among those who use electricity, as to its general and special value, and much of the prejudice that exists against electro-therapeutics is the result of a want of a knowledge of the tests by which the action of electricity on patients is to be determined.

When we give opium, we know very soon whether it relieves pain and produces sleep, or, as not unfrequently happens, has effects precisely opposite. We learn to judge without great difficulty whether the chloral and quinine are doing the work that we desire. With stimulants and tonics, as used in the chronic affections, greater difficulty is experienced, but there are certain tests which we study and look for and by which we are guided. The effects of electricity should be similarly studied.

The good effects of electrization are in general as follows:

1. *Relief of Pain and Disagreeable Sensations, Local and General.*—This relief may appear shortly after the application is commenced, after it has been continued for some minutes, or at its close. In some cases there is no relief during or immediately after the sitting, but several hours subsequently. We include painful sensations of every kind—the vague wandering pains of neurasthenia and hysteria, of neuralgia, the burning of inflammation and the severe paroxysms of dysmenorrhœa.

2. *Improvement in the Pulse.*—Where the pulse is abnormally slow it may be quickened both during and for some time after the sitting. Where it is abnormally rapid it may be lowered. The pulse, therefore, may be a guide in the administration of electricity, as it is a guide in the administration of alcohol and various other forms of stimulants and tonics. If the quiet pulse is made much quicker and so remains for some time, we may suspect that the application has been too strong or too long.

3. *Improvement in the Temperature of the Body, or of the Part which is Treated.*—Parts that are abnormally warm are cooled, or, as is more frequently the case, parts that are abnormally cold are warmed, during and subsequent to the operation. The temperature may be tested by the sensations of the patient, by the touch of the operator, or by the thermometer.

4. *General Calming Influence and Disposition to Sleep.*—Nervousness is allayed, just after taking wine, or food, or a bath, or a drive by the sea. The disposition to sleep comes on usually after the application, in rare cases during the sitting, especially when the head or neck is galvanized, or in positive static electrification by the simple method of insulation.

5. *Mental Exhilaration.*—The effect of sea-bathing, or the inhalation of oxygen, is to exhilarate in a way that defies minute analysis. The effect of electrization is similar.

6. *Increase of Appetite and Improvement in Digestion.*—In some instances the appetite is sharpened by a single sitting; the permanent improvement is, of course, a slower effect, and is only observed after a number of applications.

7. *Improvement in Local and General Nutrition.*—To accomplish im-

provement in nutrition is the great object of electric treatment. The relief of pain and of other special symptoms, during a sitting, may justly be regarded as results and accompaniments of improvement in nutrition. At a later stage of a course of treatment the improvement in nutrition may be seen and studied by the senses. Improvement in local nutrition is produced by local electrization, improvement in general nutrition is produced by general or central electrization. Peripheral local electrization may, however, reflexly produce improvement in general nutrition, particularly when prominent organs, as the uterus, the stomach, and liver, are treated.

The evil effects of electrization, by the occurrence of which we may suspect that the applications are too strong or too long, or improperly given, or that wrong methods are used, or that the temperament and disease of the patient contraindicate electricity, are, in general, as follows:

1. *Headache and Backache.*—Sudden shocks, or interruptions of the current, may cause momentary headache that passes away as quickly as it came. When the headache persists for a considerable time one may know that there has been somewhere a mistake in the application.

2. *Irritability and Insomnia.*—Patients may feel nervous, irritable, and indefinably disagreeable after an application, and the sleep the following night may be less sound and more disturbed by dreams than usual. These are evil effects, and are to be guarded against.

3. *General Malaise.*—This symptom, which is the reverse of the exhilaration spoken of among the good effects, appears not unfrequently after an overdose, especially of general faradization or of static electricity. It sometimes, though less frequently, follows central galvanization, and there is no form of local electrization, central or peripheral, that may not in some temperaments and conditions give rise to it.

4. *Excitation of Pain, or Increase of Pain already Existing.*—Neuralgia is sometimes increased on the application of the current, and particularly when the currents are strong and interruptions are made. A harsh and rough faradic current, even when mild, may aggravate pain. Sometimes there is no effect during or immediately following the *séance;* but in the course of a few hours, the pain is excited or aggravated.

Similarly the pains that accompany malignant tumors may be excited when electricity is applied during an interval, or they may be increased if treated during the paroxysm.

5. *Over-Excited Pulse.*—The pulse may indicate whether the application has done good or harm, with some considerable certainty, provided the operator is sufficiently familiar with the normal pulse of the patient. This familiarity can only come from previous acquaintance. A stranger, seeing a patient for the first time, and treating him by electricity, is quite likely to be deceived. The pulse may be over-excited by the mere coming in of a new physician, or by the thought or dread of electricity. Thus

the value of the pulse as a means of determining the degree of the ill effects of an application is much diminished. As a test of the good effects of electricity, it is much more worthy of trust.

6. *Chilliness and other Nervous Sensations.*—An application which has been made injudiciously may be followed almost immediately by a feeling of chilliness, as though the patient had taken cold. There may be also a stiffness of the neck, and pain on turning the back, as though the patient were rheumatic, and heat and burning in the spine, and crawling, creeping, pricking, stinging sensations in the face, down the back, and on the limbs and other parts of the body.

These sensations are not due to a cold, as is sometimes supposed—for, except through gross carelessness, patients do not take cold during an application of electricity—but they are merely nervous sensations, of an hysterical character, precisely like the symptoms described under hysteria and allied affections, and are due to over-irritation. They more frequently follow faradization than galvanization, especially when a hard, rough, unpleasant current is used. They appear only in the exhausted and neurasthenic, and most frequently in women.

7. *A Feeling of Soreness, Stiffness, and a Dull Aching.*—These sensations are closely allied to those described in the preceding paragraph—they are the result of over-irritation either of the nerve-centre or periphery. The soreness that is felt in the muscles after severe faradization is somewhat like that which is experienced after violent exercise in the gymnasium, on skates, or on horseback.

The dull, aching pain through the whole body is like the sensation that is experienced after taking cold. It is a purely nervous sensation and is caused by over-irritation of the spinal cord. One patient whom we treated for an exhausted and irritable condition of the cord, resulting from cerebro-spinal fever, persisted that every application caused him to "take cold."

8. *Profuse Perspiration.*—Gentle perspiration is one of the good effects of electrization; it is observed both after general and local treatment. But profuse perspiration of any part, as the head, or one of the limbs, or of one side of the body, or of the whole body, occurring during a *séance* or directly following it, is a bad symptom and indicates over-irritation. In some hypersensitive conditions profuse perspiration may appear under a very mild current, and at the outset of the application. We have known a paralyzed arm in hemiplegia break out with abundant perspiration. In cases of cerebral and spinal irritation we have known the forehead and the hands to perspire freely during the application. Some constitutions are specially impressible in this regard. We once treated a case of paralysis of the bladder by external galvanization; the patient was of the average strength and health, but in less than five minutes his whole body was as freely perspiring as in the hottest summer day. Nausea and faintness also came on and stopped the application.

9. *Prolonged Reaction of the Nerves of Special Sense.*—In the section devoted to Electro-Physiology, we have seen that the nerves of special sense, the auditory, the olfactory, the ophthalmic, and the gustatory nerves, all have their special and peculiar reactions to electricity. These reactions are normal and physiologic, but in degree and variety they are greatly influenced by temperament. These reactions are, on the part of the auditory nerve, hissing, rushing, boiling, seething sounds; on the part of the ophthalmic nerve and retina, flashes of light; on the part of the olfactory nerve, under a powerful and painful current, peculiar phosphoric or ozonic odor; on the part of the gustatory nerve, an acid or coppery taste. For the great majority of temperaments in health or disease, these reactions disappear with the cessation of the application; but where there is a special susceptibility to the electricity, or when very severe or prolonged applications have been made, some of these reactions may continue for hours or days. Thus we have known patients to complain of the peculiar taste in the mouth two or three days after an application. The buzzing in the ears also does not always stop when the current is opened. Prolonged flashes before the eyes are sometimes noticed, though but rarely. Prolonged reaction of the olfactory nerve we have never observed.

We call these prolonged reactions evil effects, because they appear in very susceptible patients, or after careless procedures, and are usually accompanied by other effects that are unmistakably evil.

Disturbances of the Nerves of Motion and Common Sensation.—Under this head we include hyperæsthesia, general or local, that an overdose of electrization sometimes produces in nervous and hysterical patients, or the opposite condition of anæsthesia and muscular spasms, contractions, and rigidity. These phenomena are not frequent, but in rare instances they have been observed; muscular spasm, where it already exists, may be aggravated temporarily by electricity.

Hygiene of Patients after the Applications.—Patients who are strong, and are treated for purely local troubles, may be entirely indifferent in regard to their behavior after electric applications; they may exercise brain or muscle, or remain idle, as may be convenient, and the improvement under the treatment will go on just the same. But delicate patients who are treated for grave conditions of debility, and especially females, do better to avoid exertion after an application; better for them to sit a while or rest on a lounge, and if they are treated in bed to remain there; and this, we believe, is another advantage in treating such cases just after retiring.

If any fancy they take cold as a result of an application, it is a pure fancy, or it is the nervous chill that sometimes follows over-electrization, or it is the result of exposure in a cold room while undressing.

Increased Toleration of Electricity.—The system can become habituated to electricity just as it becomes habituated to alcohol, or opium, or any other potent remedy. After a long course of treatment, extending over several months, nearly all patients bear very much longer and stronger applications than at first. This is observed in those whose sensitiveness to electricity is at first extreme. It is not therefore necessarily a discouraging fact if at the outset of a course of treatment very gentle currents and very short sittings are required.

The Temperament, as well as the Disease, to be Considered in Using Electricity.—There are individuals whom electricity always injures, the only difference in the effect on them between a mild and a severe application being that the former injures less than the latter. There are patients upon whom all electro-therapeutic skill and experience are wasted; their temperaments are not *en rapport* with electricity.

It matters not what may be the special disease or symptoms of disease from which they suffer—paralysis, or neuralgia, or neurasthenia, or hysteria, or affections of special organs—the immediate and the permanent effects of galvanization or faradization, general or localized, are evil and only evil. We have not arrived at this opinion by theorizing; we have been driven to it by the accumulating and irresistible logic of facts. The first query that arises, in the mind of the electro-therapeutist, when a case under his care responds badly, is, "Am I rightly using this remedy; am I making the application too long or too severe, or by improper methods? Would a change of current be desirable?" But after we have tried all electric applications; after we have gone from galvanism to faradism, from general to localized electrization, from long and severe to short and gentle treatments; after we have rung the changes on all these, and yet persistently aggravate rather than mollify the disease, and instead of strength and relief produce weakness and distress, and instead of calmness cause irritation—then we have only to make as graceful a retreat as possible, and put that patient down as a case that was not born to be treated by electricity. We have no explanation to offer of the phenomenon; and the popular belief or supposition that the excess or deficiency of animal electricity has something to do with these matters is as undemonstrable as it is plausible; he who should attempt to prove or disprove it would find that he had undertaken anything but an easy task. It would seem to come in the list of those strange but familiar likes and dislikes in regard to certain articles of food or drink, or of certain sights or odors. We know of no physiognomic or rather external appearances by which to determine whether a patient does or does not belong to the unfortunate few who can have no lot or share in electro-therapeutics. The strongest equally with the weakest, the plethoric and the enervated, are found among these Gentiles of science.

The reverse proposition, that there are certain constitutions for which, by whatever form of chronic disease they may be afflicted, electricity is always indicated, is equally true. There are patients who find in electric treatment almost a specific. Whether they suffer from dyspepsia or neurasthenia, from hysteria or diseases of special organs, rheumatism or neuralgia, electrization always relieves them up to a certain point, at least, if it does not positively cure. The broad fact to be understood is, that it is not so much the disease or the symptoms as the temperament that indicates or contraindicates electrization.

While some chronic diseases are more amenable to electricity than others, among all patients there are individuals to whom it is a matter of indifference what special affection they may suffer from; so long as improvement in local and general nutrition is indicated, they will be benefited by electric treatment.

To all this it should be added that some persons are indifferent to electricity—they can bear almost any strength of either current very frequently and for long applications, without experiencing any effect either good or evil. Electricity may be poured over them in limitless measures; they may be saturated with it, and they may come out from the applications not a whit better or worse. Patients who are quite delicate and sensitive exhibit this supreme and provoking indifference to electricity. We are inclined to believe also that patients vary in their susceptibility to electricity at different times of life. Susceptibility to stimulants and narcotics oftentimes undergoes strange modifications during the lifetime of an individual. Those who at one time cannot drink coffee, sometimes find that a few years so modify the temperament that they can drink it with absolute freedom, and *vice versa.* Similarly, also, alcoholic liquors act in a most capricious way, sometimes benefiting, at other times injuring, even when nearly all the other conditions except age are the same. Idiosyncrasies in regard to certain articles of food are by no means constant through life—they may change either way, and that too in the course of a few years; they may be modified by febrile or other diseases that revolutionize the system, or by residence in various climates, or by mere lapse of years. Analogy would lead us to suppose that susceptibility to electricity might also be thus modified, and our observations seem to convince us that such is the case.

We are further inclined to believe that susceptibility to electricity, favorable and unfavorable, like all other constitutional tendencies, is subject to the laws of hereditary descent, and runs in families. We have treated by electricity three members of the family of a physician who are afflicted with quite diverse maladies, but all of whom not only improved under the treatment, but can be electrized with great freedom by either current; and yet none of them are strong, and two of them are delicate.

On the other hand, we have treated families where several of the members are so susceptible to the electric current that the application must be made with great care lest unpleasant results occur. We are fully convinced also that the proportion of those who do not bear electricity well is larger among the higher than among the lower classes; in hospital and dispensary practice, the number of patients who exhibit excessive susceptibility to the electric treatment is quite limited, whereas in private practice, among the intellectual classes, one out of five or ten, take the cases as they run, must be treated with very considerable caution, lest disagreeable symptoms arise.

Relation of Electro-Susceptivity to Prognosis.—Between electro-susceptivity and prognosis there would appear to be no constant relation. One patient may be extremely susceptible to electricity, and another capable of bearing it in large doses, and both shall be benefited. If there be any law in the matter it is this: that those who occupy the medium ground, who are neither specially sensitive nor the reverse, offer the best prognosis under electric treatment. It is equally sure, however, that those who are exceedingly sensitive may become so tolerant of the remedy as to derive great benefit from it. For this reason we should not be discouraged, even by extreme electro-sensibility or electro-susceptibility in our patients.

The most provoking class are those who cannot be influenced in any way by electricity, but who can even from the very first receive it in enormous doses without showing or feeling any good or evil effect; and yet even such cases may by protracted treatment be benefited.

Regard for Age.—In the apportioning of the dose of electricity the only general rule to be considered is, that the extremes of life—the very young and the very old—demand rather more caution than those in youth and middle life. It is not, however, necessary to divide the doses of electricity for infants and children, as we divide the doses of ordinary medicines; children from three years down to three months and even younger may be treated by general faradization and central galvanization almost as freely as adults. On theoretical considerations, and in order to be on the safe side, we do not usually treat very young children as long or with as strong currents as adults, nor quite so frequently, but we have not often seen any especially bad results from quite prolonged applications, provided mild currents are used. The rule is to give the average baby about half as much treatment as the average adult. Children cry when the current hurts them, and this to the merciful physician operates as a check against overdosing them.

Very old patients—between seventy and ninety—need to be treated with reasonable but not extreme caution. The moderately aged—between fifty and seventy—often bear electricity better than those in the more active period—between twenty and fifty.

Regard for Sex.—As a rule females are sometimes more susceptible to electricity than males, and require to be treated with greater caution; not that there is any difference of susceptibility of the sexes, but because in civilization woman is more delicate than man, and more readily influenced for good or evil by all remedies and systems of treatment. But although the law that woman is more impressible than man holds well on the average, yet the individual exceptions are very numerous. Some women—even those who are exquisitely delicate—can bear enormous doses of electricity, while some men who are very hardy can bear none at all. The rule, however, is constant enough to make it advisable always to begin the treatment of delicate females with considerable caution.

The higher susceptibility of women to electric influence makes them yield more rapidly than men to the treatment, when it suits the temperament and disease, and hence it is that many of the most delightful results of general faradization and central galvanization have been obtained in neurasthenic, anæmic, hysterical women.

The menstrual period in women does not contraindicate electric treatment at all, but on considerations of delicacy the operations of general faradization and central galvanization cannot well be performed at that time. Local applications to the periphery can be made without regard to the menses.

Regard for the Method of Application and the Skill of the Electro-therapeutist.—It is not electricity in the abstract, but electrization—that is, electricity applied to the body—that cures disease. Everything, therefore, depends on the method of application. Patients frequently say that they have "tried electricity" and it did no good. We have long since ceased to pay any heed to such statements, or to allow them to influence our prognosis, unless it is expressly stated who gave the electric treatment, what methods were employed, and how faithfully the treatment was carried out. Some of the best successes we have are gained with patients who have "tried electricity" and found it wanting. What should we think of a patient afflicted with a broken leg who should say that he had "tried surgery," and it had failed to set the bone? Would we not ask, "What surgeon? Was he a pretender or a man of science? And did he have a fair chance?" It is possible, even if good treatment at the hands of good men failed some time ago, that the conditions may now be so altered that the same or different treatment will be successful.

It is not the remedy, it is the manner of using it that determines its value. There is as much difference in electro-therapeutists as there is in general surgeons, ophthalmologists, or aurists, or gynecologists, or obstetricians. In the ranks of those who use batteries are all grades of genius, and lack of genius, especially the latter. In electro-therapeutics three currents are used, and many different methods of application, and these methods are all capable of indefinite variations, dependent on the taste, skill, or experience of the electro-therapeutist. When one mode of application fails, another may succeed; when one electro-therapeutist fails with any mode of application, another with the same mode of application may succeed. And yet patients with some obscure disease, that requires the best diagnostic as well as therapeutic skill, who have had, perhaps, half a dozen applications of the magneto-electric or rotary machines, at the hands of some stupid servant-girl, declare that they have "tried electricity." As well might a sailor whose broken bone had been badly set at sea by a comrade before the mast declare that he had "tried surgery."

The Differential Prognosis of Accidental and Hereditary Disease, under Electric Treatment.—The prognosis of any case under electric treatment depends more on the time that the disease has been existing than on the nature of the disease itself. Very grave and severe symptoms of the most threatening character yield promptly, when they are recent, and, so to speak, a cidental, while mild and nameless symptoms, that appear to be of the most trifling character, when long standing, and especially when they are inherited, may be exceedingly obstinate. It becomes, therefore, of the first importance to inquire how long the morbid symptoms, or other symptoms allied to them, have been existing in the patient, before making a prognosis. This principle applies to all diseases for which electricity is employed. It is illustrated in a most interesting manner in hysteria and allied affections. If two cases present themselves, both suffering from symptoms of hysteria and neurasthenia, but in one case the symptoms are a life-long heritage, while in the other they have arisen recently, and, so to speak, accidentally, the prognosis in the latter case is, other conditions being the same, consequently more favorable. Even if the symptoms in the recent case be of a severer type, the prognosis may be much better than in the inherited case. On this account it becomes necessary to inquire with diligence and repeatedly, of the patients and of their friends, in order to see whether any allied symptoms have been their portion through life, and whether the special disturbances for which they require treatment are simply branches of a great tree of disease that has grown up in them from the moment of their inception.

When, for example, a patient appears with sciatica, or tic douloureux, it is not enough to learn how long that particular symptom has distressed him in the present attack. The questions to be asked are: Has he ever at any period of his life had this or any other form of neuralgia? Is he of the nervous diathesis? Have his parents or any of his near relations suffered from neuralgia, or from any disease, or symptoms of disease that are allied to it? On the answers given to these queries will depend our probable prognosis, not only as to rapidity of relief under electric treatment, but also as to its permanency.

Inherited diseases are inclined to relapse: the symptom may give way, apparently, before the force of treatment, but may reappear as easily as it disappeared, even while the treatment is continued.

After-Effects of Electric Treatment.—It is a fact well recognized that the tonic effects of a trip to Europe, or to the mountains, or on a short vacation anywhere, or at any season, are frequently but little appreciated while the patient is travelling or recreating; but appear days, weeks, and months subsequently. A debilitated man may receive no strength while on the ocean, or at the hotel, or farm-house in the country, may, indeed, seem to grow weaker instead of stronger, and may become disheartened thereby; but on his return to his duties, health may gradually, perhaps imperceptibly, come to him, and he may experience a renovation and a recuperation that can only be explained as the after-effects of his vacation.

It is, perhaps, not so well recognized that tonic remedies, and systems of treatment of various kinds, may act just in the same way. Not only the evil but the good effects of medicines may be cumulative. We may see this principle illustrated in the administration of quinine, strychnine, arsenic, phosphorus, and iron.

Electricity obeys the same law, and in certain constitutions and certain states of the system, especially those of debility, it does little or n thing that the patient can see or feel during the treatment itself—but prepares the way for a perfect and permanent recovery. We have seen this principle illustrated in a large variety of cases of chronic disease. The practical lesson that we are to derive from this is to encourage patients who do not feel fully satisfied with the progress that they make while under treatment, to watch closely, if possible, their career long after treatment is abandoned.

Electrization in its Relations to other Forms of Treatment.—The question, so often asked, whether electric treatment will interfere with internal medication, or with gymnastics, the Russian, Turkish, or other baths, and so forth, is very easily answered. It harmonizes with all other tonic remedies and methods of treatment that are employed for the common purpose of relieving pain or building up broken-down constitutions.

Except in cases where we wish to experiment and learn the therapeutic value of electricity by itself alone, uncomplicated with other healing factors, it is a positive advantage oftentimes to employ, at the same time with electricity, external or internal medication of various kinds. So far as we now know there is no medicine that is incompatible with electricity. There is no evidence that any remedy has any specific reinforcing effect upon ele tricity, such, for example, as certain stimulants have on hydrate of chloral. Some of the best therapeutic results are obtained from a combination of electric with other treatment.

On the Use of Electricity by the Laity.—Even at this advanced stage of electro-therapeutics, it seems to be necessary to constantly warn the profession against indiscriminately entrusting the details of electric applications to the nurses, friends of patients, and the patients themselves. Having just rescued this department from the hands of the laity, and given it a position among men of science, it seems strange that those physicians who are familiar with the subject should even now use their influence to return it to the people at whose hands it formerly suffered so much; to restore it to the captivity of prejudice and ignorance.

The temptation on the part of the people to use electricity themselves, and on the part of the profession to allow them to do so, is very strong. The majority of physicians know little more of electro-therapeutics than their patients. Some have a theoretical, but not a practical acquaintance with it. Then there are those who are well practised in the art, but are too closely occupied to employ it. They have no apparatus, or if they have any it is very likely out of order. Perhaps no specialist is accessible, or the patient is, or is supposed to be, too poor to employ one. The physician, forgetting that it is not electricity, but electrization that cures disease, forgetting that there are three kinds of electricity in common use, and many different methods of application, every one of which is capable of various modifications, forgetting that there are certain temperaments that will not bear electricity, however applied, and that there are others who must be treated at first with great skill and caution, and on whom the currents and methods employed must be studiously varied during a course of treatment; in short, forgetting that electro-therapeutics, considered as a science or an art, is wonderfully complex and exacting, orders the patient to "get a battery and try electricity."

Abbreviations Used in Electro-Therapeutics.—It is a decided convenience and saves much time in recording cases, in giving private instruction, in public lecturing, and in conversation, to describe electric applications by abbreviations. We therefore suggest the following abbreviations, which have been used with satisfaction in giving private instruction and in conversation with our assistants and others who are familiar with it, and in records of cases from day to day:

L. F. Localized faradization.
L. G. " galvanization.
G. F. General faradization.
C. G. Central galvanization.
G. B. Galvanization of the brain.
G. C. S. " " sympathetic.
G. S. " " spine.
B. F. Bi-polar faradization.
S. E. Static electrification.
S. B. " breeze.
S. S. " spark.
E. Electrolysis.
G. C. C. Galvano-chemic cauterization.
G. C. Galvano-cautery.

CHAPTER IV.

THE DOSAGE OF ELECTRICITY.

The Galvanic Current.—The more thoroughly one studies electro-therapeutics in all its relations, medical and surgical, the clearer it becomes that the real scientific basis for the use of electricity in medicine and surgery is found in electro-physics more than in electro-physiology. The *rationale*, therefore, of the various methods of electrization, of electro-cauterization, and the important department of electrolysis, can be satisfactorily understood only by those who have grasped the elementary principles of electro-physics—the laws of resistance and conductibility, and, above all, the law of Ohm. Those who have been once well-grounded in these laws of electro-physics find that the various special problems that arise, whether of a theoretical or practical character, very quickly resolve themselves. In some conditions and with some individuals the difference in result between a very gentle and short application and a very strong and protracted one is nothing more or less than the difference between agreeable success and painful failure, while in other conditions and with other individuals the difference between success and failure is measured by the difference between strong and short applications and mild and protracted ones.

There are persons who must be treated not only mildly, but at long intervals; and there are persons with perhaps the same maladies that can bear, with advantage, powerful and frequent applications; to distinguish between these classes and the various gradations that lie between the extremes of tolerance and of susceptibility is the first duty, and oftentimes the hardest study, of him who makes much use of electricity in medicine. To state in definite terms the solution of the problem of electric dosage as it relates to these various classes and gradations is a task that we by no means propose to undertake. The ability to measure with the utmost nicety the strength of the current does not solve the problem.

Such precision may be of the utmost value in the continued treatment of any given case of neuralgia, for example, but the strength then used may in no way answer for the next case, and, therefore, recorded statements of the number of milliamperes used in different forms of nervous disease especially are by no means as valuable as one might be led to believe.

A clear appreciation of the fact that the human system reacts to no drug with such varying susceptibility as to electricity is one of the first and most important lessons to be learned.

When we come, however, to the department of electro-surgery as represented by electrolytic action, the case is widely different. To produce certain local effects requires a certain definite expenditure of force, and the question of idiosyncrasy cannot be so much considered, although even here it is not to be altogether ignored.

The milliamperemeter has been used in therapeutics only a comparatively short time, but for many years nervous as well as other diseases have been treated by electricity, with different degrees of success, according to the individual experience and skill employed in its use. Personally, although acknowledging the great utility of accurately measuring the strength of the current, we cannot claim greater success in the treatment of most nervous diseases, now that the milliamperemeter is employed with every application, than formerly when it was unknown, and this experience is, we fancy, common to all those who have through years of work become practically familiar with the routine of electro-therapeutic treatment. It is, notwithstanding, an immense convenience. It relieves the mind of all anxiety in regard to many minor details, and he who has once tested it will never willingly be without it. To the tyro it is a necessity.

Without it he will find himself working entirely in the dark, and a beginner should no more think of attempting serious work without his indicator of current-strength, than he should administer his drugs without his apothecary's measure. Another appliance convenient to have, but in no sense essential, is the rheostat, the utility of which we will briefly illustrate. To-day, for example, the observer notices that the current from a given number of cells is painfully felt by the patient, while to-morrow the same strength applied to the same patient may be felt but slightly. If no milliamperemeter is used, the mystery seems very great.

If, however, the current is measured the mystery is solved, for it is observed that when pain follows the application, a greater number of milliamperes is registered than when no pain is produced.

All this is explained by the fact that the skin varies very much on different days and in different physical conditions as to its conductivity.

Now if on one day, in an application to a patient of a current from thirty cells, the meter registers thirty milliamperes, and on the next the same number of cells, with the electrodes applied on the same portion of the body, causes the meter to indicate but twenty, we know that there is a far greater resistance to the current on the second day than on the first. It is not essential, for practical purposes, that we know just what that resistance is, but it is desirable and interesting to know, and the rheostat supplies this knowledge with absolute exactness. In order to find out the resistance when the registration is thirty, we substitute a rheostat for the body of the patient and introduce a number of ohms in the circuit sufficient to hold the needle at thirty. If the number of ohms found necessary is three thousand, then three thousand is exactly the resistance offered by the body of the patient on the first day. To find out the resistance when the meter registers but twenty, the same process is repeated, and if the number of ohms registered is five thousand, we know that five thousand ohms is the amount of resistance offered.

The utility of the rheostat in therapeutics is more especially in the direction of enabling us to increase or decrease the current gradually and without shock. After intercalating a resistance of one thousand or more ohms we bring into action the number of cells that will probably be required. By gradually reducing the resistance in the rheostat, the milliamperemeter soon marks the degree of quantity required. To decrease the current the resistance in the rheostat is gradually increased until the needle points to o, an indication that the resistance equals the strength of the current. The Germans taught the use of ridiculously weak currents, and, influenced by these teachings and by a natural respect for an agent so subtle, the average degree of strength employed when first we began the use of electricity, and for years subsequently, indeed, was in many cases entirely inadequate. In the applications to the head ten or twelve cells were, as a rule, considered quite sufficient. Beneficial results were often seen to follow such mild treatment, it is true, and it was seldom that more was attempted, but that the dose of electricity thus obtained was exceedingly slight, and far more inefficient than was then supposed, can be readily demonstrated. The cephalic electrode was a broad, thick sponge, while the other, applied generally to the pit of the stomach, was of sponge also, but much smaller. The resistance thus offered is necessarily very great, and if the milliamperemeter is used, it will be found that the actual quantity of electricity passing through the body of the patient hardly exceeds four or five milliamperes. Now, to use a current of only this strength in applications to the nerve centres is, as a rule, little more than child's play, and we make this assertion in remembrance of the fact that we formerly advocated the efficiency of currents even milder than this. Sometimes benefit may undoubtedly accrue from these very mild applications, but we have for so long a time observed the effects of a bolder line of treatment that we have no hesitancy in advocating it in preference to former methods.

In place of a current strength of four or five milliamperes, substitute one of twenty, and the superiority of results will soon become manifest. But if, by the method in common use, twelve ordinary cells, in the treatment of the head, deflect the needle but about five degrees, it would take some forty-eight cells to give a strength of twenty milliamperes, and few physicians have any such number at command as that. For this purpose the electrodes should be as large as possible—that is, broad and flat, or curved according to the part of the body to which they are applied, but with little bulk.

With electrodes such as these and a series of eighteen Leclanché cells, a current of twenty milliamperes can readily be obtained in applications from the head to the solar plexus. Thirty-six cells would therefore give forty milliamperes, an intensity of current seldom necessary in central galvanization. In applications to the mucous membrane of the uterus and vagina, where the resistance is far less, the same number of cells will cause the registration of the milliamperemeter to run up into the hundreds.

In making these strong applications to the brain there is an element of danger which cannot be emphasized too strongly, and that is the possibility and, indeed, the probability, considering the utterly haphazard way in which electricity is too frequently used, of the current becoming suddenly broken.

Even with very weak currents applied to sensitive nerves, or to the head, interruptions are as a rule undesirable, and when strong, as indicated by a deflection of the needle of twenty or more, they may painfully aggravate the very symptoms that you are endeavoring to allay. As an illustration of this most important fact we may be allowed to refer to two out of a number of cases upon which this statement is based. The first was a case of epilepsy; one which had been helped, up to a certain point only, by a persistent use of the bromides, but which had very greatly improved and finally recovered, when this treatment was supplemented by galvanization of the brain.

The attacks had been growing far less frequent, and at this time some three months had elapsed since the last. The patient was feeling exceedingly well, and this in itself was with her regarded as a guaranty of exemption; for invariably, before a paroxysm, she was accustomed to feel far from well. With one pole at the epigastrium and the other on the head we were gradually increasing the current, until it probably indicated some fifteen or twenty milliamperes. In some way the connection was suddenly broken, and, with the characteristic cry, the patient fell over in an epileptic fit, and, as we afterward learned, one of far greater severity than usual.

The other was a severe case of chorea of long standing. This patient was slowly but surely recovering, and had so far regained command of his lower limbs that he could walk with but slight evidences of any lack of co-ordinating power, and could use his knife and fork with ordinary readiness. About this time he inadvertently received a shock through the head of a current strength of some twenty milliamperes. Results of a most unpleasant character followed. The choreic movements of the legs and arms returned in a marked degree, so that he walked with uncertain step, and could no longer feed himself. These aggravated symptoms continued for about ten days, and then began gradually to subside.

We would by no means be understood to say that a galvanic shock, even though severe, will usually cause marked increase of symptoms that are subsiding under the use of an uninterrupted stable current. Such shocks are many times given without any apparently evil results. They should, nevertheless, be guarded against in every possible way, as their tendency is undoubtedly harmful. One of the diseases to which we will refer in giving more definitely our own experience in regard to electric dosage is epilepsy, a condition in which electricity is far from being generally recognized as capable of any special service. We are not aware that in this connection the disease has been discussed in any treatise or article excepting our own. As far back as 1878 we wrote upon the subject, and later gave, before the New York Academy of Medicine, the results of our observation in twenty-eight cases.* Of these twenty-eight cases of epilepsy almost all of them were treated without the aid of accurate current measurement, since the milliamperemeter in therapeutics is of comparatively recent introduction. It is, however, possible to give approximately the strength of current used in most of these cases.

The range was between fifteen and forty milliamperes. We have found no patient suffering from epilepsy who could not endure, without ill effects, a current of fifteen milliamperes, provided the cephalic electrode covered a surface sufficiently large and was accurately adjusted, while most of them bore without discomfort a much stronger current. Seldom, if ever, should we regard more than thirty milliamperes desirable, and the strength that we have found most generally acceptable, and of service to our patients, has been from fifteen to twenty milliamperes. In chorea, substantially the same rule prevails in regard to strength of application, or would prevail, if the average age of choreic patients was not much less than that of epileptics.

The strength of current applied to the head in a case of chorea under twelve years of age should rarely exceed twenty milliamperes, and generally should be about twelve. We cannot approximate the relative dose of electricity for different ages as accurately as we can that of drugs. This observation, however, will be found to be uniformly correct: The very young bear proportionately very much stronger currents than adults. A child of three, who should, according to rule, tolerate only about one-fifth the adult dose of any powerful drug, will easily bear one-third the adult dose of electricity.

Old people bear stronger currents than those in middle life; it is, indeed, quite astonishing to observe the very marked insusceptibility of some very old people to electricity, due in some measure, perhaps, to blunted sensibility, but in a higher degree to a loss of conductivity of the

* New York Medical Journal, April 16th, 1887.

tissues, and especially the skin. It will not answer, however, to presume too much in the application of electricity to the old on account of this apparent insusceptibility, as it is not uncommon to meet with patients advanced in years who, while they may feel the application of a certain strength of current but little at the time, yet are exceedingly susceptible to its secondary effects. Another disease for the relief of which the galvanic current is but indifferently appreciated is exophthalmic goitre. Without it, indeed, it is often impossible to obtain results at all satisfactory, but with it marked amelioration of the symptoms almost invariably follows, and complete recovery, many times, in cases that respond but slightly to other methods. The strength of current indicated varies according to the position of the poles. An important point for local application is the auriculo-maxillary fossa, immediately below the lobe of the ear, where but a comparatively small electrode can be used.

A strong current would produce both pain and vertigo, and five to seven milliamperes is about all that will be well borne with the electrodes in this position.

As we gradually move the pole down along the inner border of the sterno-cleido-mastoid muscle, the strength can be increased very materially, and with a large pole at the back of the neck, near the sixth cervical vertebra, and the other on the enlargement, currents of twenty and thirty milliamperes and even more can be profitably utilized.

The variation of current strength in the treatment of neuralgia and pain in general is as wide as the symptoms are varied in character and seat, and more, perhaps,than in disease in general is it necessary to carefully discriminate in the selection of the proper current.

True neuralgia (pain directly along and confined alone to the course of a nerve) calls almost invariably for the galvanic current, while the so-called pseudo-neuralgias, which are simply forms of pain occupying certain areas, and running seemingly in the direction of certain nerves, yield most readily to faradism.

Five to ten milliamperes are, as a rule, amply sufficient for the relief of neuralgia about the face and head, while in sciatica it is often necessary to use as high as forty and fifty, or even more. The efficacy of very strong currents in the treatment of sciatica should be more generally recognized.

As ordinarily used it often fails to relieve, because of an insufficient current. The operator is simply self-deceived. He is using perhaps a large number of ells, freshly and properly charged, but his electrodes are of a pattern and size to offer the greatest possible resistance. Let him substitute electrodes that are broad and flexible, readily adapting their shape to every inequality of surface, and this difficulty of lack of strength will quickly resolve itself. In the treatment of paralysis, whether central or peripheral, the dose of electricity is determined by so many modifying factors that it cannot be fully discussed here. The general law, that when a muscle fails to respond to the faradic current recourse must be had to the galvanic, is now usually appreciated, but it is not so generally understood that paralyzed nerves are not to be indiscriminately stimulated by sudden shocks. Many a paralysis that might have recovered has been made permanent by such ill-directed and culpable interference. After it has been determined, by careful interrogation of the affected muscle, what is the degree of quantitative or qualitative change, it is in many cases imperative to use the continuous and not the interrupted galvanic current. Especially is this true in those cases of local paralysis where responses utterly fail to be elicited by the faradic current, but are more readily obtained by the galvanic current than in the normal condition of nerve and muscle. In such cases mild currents of about seven milliamperes, increased to twelve and fifteen as improvement increases, and applied without interruption, will succeed in lessening the irritability of muscular fibre and in restoring the lost vitality of the intramuscular nerves, upon the integrity of which the faradic current depends for its ability to call forth muscular contractions, far more effectually than when interruptions are attempted.

In most forms of paralysis, however, much stronger currents than these can be applied. In infantile paralysis fifteen or twenty milliamperes may be used, and in the spinal paralysis of adults (poliomyelitis) twenty-five to thirty are usually indicated. In both these conditions, but more specially in infantile paralysis, the same rule should be observed as in the treatment of the form of facial paralysis to which allusion has been made—for the most part continuous and not interrupted currents. Given a case of infantile paralysis in which reaction to the faradic current is entirely lost and only faintly appreciable to the galvanic, it is entirely possible, by sudden shocks in the beginning, to quite obliterate the little remaining vitality and render the case incurable. In hemiplegia, again, while electricity possesses but a limited value, it is yet capable of doing decided harm. We have at this time under observation a hemiplegic patient, whose arm was in such a condition of heightened irritability that contractions to both currents were called forth far more readily than in health. He fell into the hands of one who possessed greater activity than insight, and was subjected to a series of treatments by the faradic current in which the muscles of the arm were jerked about in a most merciless manner. As might have been expected, there soon supervened an entire loss of motility, together with neuralgic pains of a distressing character. In alluding to epilepsy and chorea we spoke of central galvanization and its dosage in those diseases. Central galvanization is also a valuable method in many neurasthenic conditions, in hysteria, and in cases of melancholia. We illustrate in Fig. 51 the process which has given us most satisfaction.

The hair being thoroughly wet, a light wire-gauze helmet, lined with some soft, conducting material, is fitted as accurately as possible to the head. To this is attached the positive pole, while the negative is applied to the pit of the stomach, and a current passed, varying according to the disease and individual idiosyncrasies, from five to forty milliamperes.

It may seem an easy thing to make use of central galvanization satisfactorily, but, like most easy things, its efficient use demands knowledge, care, and some experience, all of which are within reach of those who desire to utilize the method. The wide area which this helmet-electrode covers lessens by just so much the resistance to be overcome, and enables

FIG. 51.

us to pass through the head a current of many milliamperes without pain or other ill results. To this end, however, the electrode must be made to adjust itself accurately to every inequality of surface, otherwise a painful concentration of current will be felt at various points, and the efficacy of the applications interfered with.

Any discussion of the subject of electric dosage would be incomplete without reference to gynecology, in which electricity has accomplished much good. Here, more than in any other department of medicine, is illustrated the great superiority of strong and comparatively short, over weak and prolonged applications. As this matter, however, is sufficiently considered in the chapter devoted to diseases of women, it need not be discussed here.

The Faradic Current.—The graduated scale on some of our faradic machines and which indicates the number of inches that the rod or helix or tube is moved, is a practically useless guide, except as far as it may be resorted to, to encourage and amuse silly and weak-minded patients. In any faradic machine the strength of the current in the cell, and consequently the strength of the induced current in the coil, varies from day to day, and varies during the application; and the amount that passes through the patient is dependent on the size of the electrodes, and the amount of moisture in them, and their relative position.

Endelmann and others have constructed faradimeters which are interesting and suggestive, but none yet has been made that is practically trustworthy. Monell's alternating current meter for determining faradic dosage for purposes of record is a useful contrivance, but for operative employment we are compelled in practice to depend on these two indications:

1. The sensations of the patient.

Very fortunately the sensation of the patient during the application indicates with considerable correctness whether the current is of the proper strength. The rule is that where strong currents are borne without discomfort strong currents are beneficial; where only mild currents are borne only mild currents are indicated. The difference in the natural sensitiveness of patients to electricity is very great. This difference is further modified by disease. In anæsthesia, local and general, in sclerosis of the nerve centres, and certain local affections, very powerful currents cause but little pain. On the other hand, in hyperæsthesia, in hysteria and allied affections as a rule, and in acute and subacute local inflammations, only mild currents can be borne. To disregard the feelings of the patient and make the applications exceedingly painful will tend to produce the evil rather than the good effects of electricity. To give only mild applications when strong ones could be well borne is to rob the patient of a part of the benefit to which he is entitled.

To the rule that the sensations of the patient are the guide in electric applications there are some exceptions, just as there are some exceptions to the rule that the appetite is the guide in the quantity of food that we eat. It is partly to guard against these exceptions, and to keep on the safe side, that the first few applications on a new patient, whom we have not before treated by electricity, should be mild and short.

Not only do different individuals vary in their sensitiveness to electricity, but different parts of the surface of the body in the same individual also vary, as we have seen through a considerable range; and in the cavities of the body and on the mucous surface the range of variation in sensitiveness is yet greater. The mucous membrane of the mouth, tongue, urethra, is very sensitive, and this sensitiveness should be respected by the electro-therapeutist.

There are some quite rare cases of hysteria where the great sensitiveness of the patient may be disregarded, or chloroform or ether may be administered. The sensitiveness of the patient is a guide only or mainly in regard to the strength of the current. In regard to the length of the application we must be guided by—

2. *The Immediate, Secondary, and Remote Effects.*—This second guide serves to correct the mistakes of the first. A meal that disagrees with us may show its ill effects in a few minutes or hours, or the following day. Similarly we should study the effects of electric applications. So far as any one or all of the good effects described in this chapter follow an application, so far we may judge that the application has done good; so far as any or all of the evil effects described in this chapter follow an application, we may judge that it has done evil. The evil and the good effects may sometimes be associated. To rightly interpret these effects, and to distinguish between those that are produced by moral, hygienic, or medical causes is one of the severest tests of medical skill. There is less liability to deception in studying the immediate effects, since there is less chance for other forces to complicate the results. After a few hours, the complications of diet, exercise, weather, medicine, and so forth begin to appear, and obscure the effects of the electricity. The secondary and remote effects can therefore only be ascertained by repeated observations. A single application gives us little opportunity to answer the question whether electricity is really the remedy that the case requires.

One caution must not be forgotten: the immediate and secondary effects may be evil while the remote effects may be good.

A long walk that much fatigues us is often beneficial, though the benefit does not appear for several days. Those who take travelling vacations to recruit exhausted energies frequently feel worse while they are travelling, but are stronger on their return and for months following. The fatigue and soreness and stiffness that sometimes follow skating and gymnastics, and other exercises, do not always indicate that benefit has not been derived. The next day the appetite and spirits may be better, sounder sleep may follow; the evil and the good effects contend for the mastery, and the good effects triumph.

CHAPTER V.

COMPARATIVE VALUE OF THE GALVANIC AND FARADIC CURRENTS.

Much of the confusion that exists concerning the differential indications for the use of the galvanic and faradic currents arises from an imperfect or erroneous or exaggerated conception of the distinction in their physical and physiologic effects. The general belief or supposition is, that there is between them a radical and important difference in kind, as though they were two different agents or forces.

We can most intelligently compare the therapeutic effects of the two currents, if we first compare their physical characteristics and their physiologic effects.

By referring to the section on electro-physics, it will be seen that both currents—faradic and galvanic—are capable of producing chemic decomposition, of deflecting the needle of the galvanometer, of producing sparks, and of being changed into heat. Generally speaking, these effects are produced more powerfully by the galvanic current; but in Gramme's machines we shall see that magneto-electricity is capable of producing great heat and of electroplating on an enormous scale.

Both currents are obedient to the law of Ohm, with this qualification, that the faradic current must be regarded as having passed through a great resistance.

Faradic, galvanic, and static electricity are therefore the same force—electricity, only each variety is modified by the nature of the substance through which it circulates, as well as the manner of its production.

Light is light, whether its waves are shorter or longer, and in spite of interference and polarization, and whatever may be the color that it excites in the retina; sound is sound, whether its undulations move slowly or rapidly. So electricity is electricity, however generated or however modified by the medium through which it moves; and all forms of it, magnetism, as well as franklinism, galvanism, and the many varieties of faradism, are merely different expressions of the one great force—electricity.

In their physiologic effects the two currents approach each other even more closely. It is true that the phenomena of electrotonos have only been demonstrated under the galvanic current; but it is not proved that similar phenomena, to a less degree, may not be caused by the faradic current, and every-day experience in electro-therapeutics shows that with the faradic current, as with the galvanic, the positive pole is the more calming, and the negative the more irritating. Both currents act on the skin so as to modify the circulation, the galvanic having a greater chemic effect and causing a feeling of burning, while the faradic causes a feeling of stinging and pricking. Both currents applied to the brain and spinal cord excite contractions of peripheral muscles. Applied to the sympathetic both currents, according to the degree of irritation, cause contraction or dilatation of the cerebral vessels; the faradic producing the same effect as the galvanic, only more slowly. Applied to the pneumogastric, whether cut or injured, both currents produce about the same effects on the heart. Even in their action on the nerves of special sense the currents approach each other far more closely than has been supposed.

In temperaments of a high order of susceptibility the faradic current may so excite the retina as to cause flashes before the eyes, and may produce a metallic taste in the mouth, and even the auditory nerve responds to the faradic current, though less distinctly than to the galvanic current, and without the peculiar differential action of the poles.

Applied to motor and sensory nerve branches, both currents and both poles cause sensations of pricking, tingling, and numbness, and contractions of the muscles which the nerve supplies. Applied to voluntary muscles both currents cause contractions, the faradic more readily than the galvanic; applied to involuntary muscles both currents cause slow contraction at both poles and in the intermediate region. The electrolytic action of the faradic current on the blood or on the tissues of the body is but feeble as compared with that of the galvanic current; but that it exists, and from the inner, or primary coil, is easy of demonstration, and yet it must be confessed that in their chemic action the currents diverge more widely than in any other physiologic effect.

Over nutrition both currents and both poles have a powerful influence, the faradic acting more prominently through the muscular, the galvanic through the nervous system.

From the accumulating results of experiments and experience in electro-diagnosis and therapeutics, we think that there is strong reason for regarding the essential distinction in the effects of these currents on the body as mainly of degree,—practically amounting, it is true, to a difference in kind,—and that this is the scientific basis for their differential employment.

In the form of localized electrization both can produce muscular contractions in paralyzed muscles, and relieve local neuralgias; both cause absorption of abnormal secretions; and both can directly affect the brain, spinal cord, sympathetic, and all the internal organs, producing in different degrees the various therapeutic results that directly and indirectly flow

16

from electrical excitation of these parts. In the form of general electrization both currents, besides producing most of the other results of localized electrization, act as powerfully stimulating tonics, and thus form most efficient aids in the relief and cure of nervous exhaustion, nervous dyspepsia, constitutional neuralgia, and of a wide range of nervous diseases associated with or dependent on general debility.

In electro-surgery both currents avail to discuss tumors, heal ulcers, and hasten absorption, although for these purposes the galvanic is incomparably the more effective.

And yet the difference in degree between the effects of the two currents is so marked and so clearly demonstrable, as to be practically equivalent in certain instances to a difference in kind, and to give very important and remarkable advantages to one current or the other, according to the indications required.

The advantages of the galvanic over the faradic are:

1. It possesses a far greater amperage; it therefore affects the brain, spinal cord, and sympathetic more powerfully than the faradic, since the anatomical position of these parts is such that it is this special quality of the galvanic current required to overcome the considerable resistance offered. For the same reason it is usually to be preferred when it is desired to affect the middle and internal ear, and the retina.

2. A power of producing muscular contractions in cases where the faradic fails. This peculiarity of the galvanic current has now been observed so frequently, and in such striking instances, that it has become an accepted fact of electro-therapeutic science. After a certain amount of treatment by the galvanic current the paralyzed muscles frequently resume their susceptibility to the faradic.

3. A far more potent electrotonic, electrolytic, and thermic action. The chemic power of the galvanic current is most markedly seen when used for the purposes of galvano-cautery or electrolysis. The superior efficacy of the galvanic current to the faradic, so often observed in the treatment of neuralgia, of atrophied muscles, rheumatism, is probably due to its greater "catalytic" action. It probably induces more rapid and more important molecular and other changes in the tissues.

The advantages of the faradic over the galvanic current are these:

1. By virtue of its frequent interruptions it more easily produces muscular contractions when passed over the muscles or the nerves that supply them. In order to produce full muscular contractions with a galvanic current of moderate strength it is necessary to interrupt the current, and, unless it is quite powerful, to localize at least one of the electrodes over the motor nerve by which the muscle is supplied—that is, over the so-called "motor points." On the contrary, the faradic current is in a condition of rapid interruption and produces contractions when indifferently

passed over the surface of the muscle, as well as when localized on the main motor nerve that supplies it.

This advantage of the faradic current is best appreciated in general faradization, the powerful tonic effects of which, as will be seen, are partly and quite largely due to the passive exercise and consequent oxidation and other important changes of tissue that result from the several thousand muscular contractions that take place during an ordinary sitting. In localized electrization this advantage is not so clearly and strongly marked, since, in this method, by a proper knowledge of electro-therapeutic anatomy and sufficient care, it is possible to direct one of the electrodes on the "motor points;" and yet even here the faradic current is much more convenient, because its employment requires no arrangement for interruption, and less minuteness of attention to the situation of the motor nerves. The exceptional cases of paralysis, where the muscles have lost their susceptibility to the faradic current, do not interfere with the general rule.

2. It produces greater mechanical effects. The mechanical effects of the faradic current are due to its rapid interruptions, which cause contractions not only of the muscles, but also of the contractile fibre-cells, thus stimulating the circulation, and with it the processes of waste and repair. In this respect its action is similar to that of rubbing, pounding, movements, and vibrations. These mechanical effects are especially indicated in the treatment of diseases of the abdominal viscera, which are supplied with contractile fibre-cells; anæsthesia, and general muscular debility.

3. It is less likely to produce unpleasant or harmful effects, when incautiously used, than the galvanic.

To confirm this statement we rest mainly on the evident results of clinical observation. We may indeed refer to a number of cases of severe constitutional neuralgia, and excessive nervous exhaustion where the faradic current invariably relieved, and where the galvanic current as invariably aggravated, the symptoms. For this reason it is better to begin the practice of electro-therapeutics with the faradic current, and for those families who desire a scientific plaything, the faradic machine is safer than the galvanic apparatus.

In all applications to the head, neck, and spine especially, applications of the galvanic current can rarely be protracted without injury, while in many cases the spine and neck may be faradized through very prolonged sittings, with positive benefit to the patient. To the head, also, a faradic current of a proper quality may be applied much longer than a galvanic current, before unpleasant dizziness or headache is excited.

A consideration of some practical importance with general practitioners is, that the faradic apparatus is more convenient, more portable than even the compactest galvanic apparatus that has yet been devised. It is impossible, however, for any practitioner to realize anything like the full benefit of electrization without apparatus for the galvanic as well as the faradic current.

CHAPTER VI.

THE PRINCIPLES OF ELECTRO-DIAGNOSIS (ELECTRO-PATHOLOGY).

In this chapter we shall speak only of the principles on which electricity is used as a means of diagnosis in medicine. The details and special applications of these principles will appear under the various diseases.

A history of the use of electricity as a means of diagnosis would very likely be the history of electro-therapeutics itself. As soon as men began to use the voltaic pile in the treatment of paralysis and kindred diseases, about the middle of the last century, just so soon, probably, they began to test the power of the electric current to diagnosticate disease. We logically infer that electrization was used as a means of diagnosis much earlier than the published treatises on the subject would show, from the fact that it has been so used—in a blind and empirical way, it is true—in this country, for thirty or forty years. Mankind, always and everywhere, are superstitious, credulous, ready to receive whatever approaches them with an air of mystery, much more so in the last century than in the present; and it is certainly not unfair to suppose that the earlier experimenters in this department consulted, to a greater or less extent, the diagnostic or prophetic power of the subtle agent—electricity. Their experiments, we may suppose, were unscientific and unsatisfactory. They were probably neither based on any well-defined principles, nor conducted by any intelligible system. Accordingly, they secured very few tangible, or at least communicable, results, and if scientific men had not espoused the cause of electro-therapeutics, the phrase electricity as a means of diagnosis would never have been known. Nearly all that has been accomplished in a scientific way, in this department, is comparatively recent; though Marshall Hall earnestly called the professional attention to the fact that electricity might assist us in differentially diagnosticating paralysis as far back as 1839.* Since that time the subject has been studied by nearly all the prominent workers in the department of electro-therapeutics.

In order to be expert in electro-diagnosis, it is necessary to be thor-

* Medico-Chirurgical Transactions. 1839.

oughly familiar with the normal reaction of the different parts and organs of the body to faradic and galvanic electricity. The foundation principles, on which Electricity can be made a means of diagnosis of disease, are simply these four:

First. The fact that all the parts and organs of the body are more or less sensitive to the electric current, and that this sensitiveness is modified by disease. This electro-sensibility may be either increased or diminished.

If an electric current be passed through a boil, or irritable ulcer, or the skin, like any other irritant, it excites more pain than when it is applied over the healthy skin; and this pain which it causes usually bears quite a direct proportion to the nature and condition of the morbid process. This is so familiar and so apparent an example of increase of electro-sensibility that to state it is to demonstrate it. The electric currents, during the various processes of electrization, penetrate beneath the skin, and, as it has been experimentally and practically demonstrated, traverse, to a greater or less extent, the principal vital organs. It is evident, therefore, that those organs which are abnormally sensitive, through disease of any kind, must feel the current much more appreciably than when in a condition of health.

But the mechanical effects of the electric currents work both ways, and organs which are indurated or changed into an anæsthetic condition by disease are less sensitive than is normal to the electric current, just as they are less sensitive to any other mechanical cause acting upon them.

Accordingly, we find that when even powerful electric currents are passed through an indurated joint, or an atrophied liver, or any part the sensory nerves of which are paralyzed, they may produce little sensation.

Before making examinations to determine the sensitiveness of the different parts of the surface of the body, it is necessary to know their relative normal sensitiveness, as indicated and described in the chapter on Electro-Therapeutic Anatomy.

No Absolute Standard of Electro-Sensibility.—We have no absolute or mathematical standard of electro-sensibility by which to compare the deviations that appear in disease. We can only compare the sensitiveness of parts with the average sensitiveness of the same parts in health. When half the body is diseased, as in hemiplegia, it may readily be compared with the electro-sensibility of the healthy side. In all these examinations into sensibility we are dependent on the statements of the patient, and the results will be influenced by his intelligence and honesty.

It need hardly be said that the diagnosis obtained by observing this increased or diminished sensitiveness of any part or organ must, of necessity, be a very general one. It simply informs us of, and directs our attention to, the fact that such a part or organ is in some way diseased. The special nature of this disease must be determined by the ordinary means of differential diagnosis at our command.

This sensitiveness to the electric current is particularly marked over the prominent nerve-tracts, and in those regions endowed with great tactile sensibility. If even a mild current be applied at those points on the upper or lower limbs where the prominent nerves are superficial, a feeling of tingling or numbness is felt through the branches of the affected nerve; and if the current is very much increased in strength, a decidedly anæsthetic effect is experienced. In paralysis of sensation, or anæsthesia, this feeling of tingling, thrill, and numbness is very much diminished under the influence of the electric current, or is entirely absent. It is on this principle that electricity becomes a most valuable means of diagnosis in the various stages of anæsthesia. A condition of anæsthesia or analgesia (loss of sense of pain) can readily be detected by the brass ball employed in general faradization, or by the metallic brush, or by any other form of electrode. To detect analgesia the electrode should be moistened so that the current may penetrate the epidermis.

General faradization is found to be of practical utility in aiding us to determine the locality of certain diseases, if not their precise nature. In dyspepsia, electrization often reveals great sensitiveness in the epigastric region, and on the left side over the spleen. In severe dyspepsia, accompanied by emaciation, a current is sometimes painfully transmitted from the middle of the back to the neighborhood of the epigastrium. A peculiar sinking sensation is sometimes felt at the pit of the stomach when a strong current is applied over the seventh cervical vertebra, or over the brachial plexus. All these symptoms, taken together, undoubtedly suggest an aggravated case of dyspepsia, and usually of the nervous variety. Congested or irritable states of the liver are revealed by an abnormal and peculiar sensitiveness when the current is applied over the right hypochondriac region. Care must be taken, however, not to confound the normal sensitiveness of the superficial nerves over the ribs with an abnormal condition of the liver. There are certain diseases of this organ in which it is less sensitive than usual to electrization, and sometimes it appears to be decidedly anæsthetic.

It may be said in general that those diseases which cause the liver to be sensitive to external pressure also cause it to be sensitive to electrization. The same general principle will apply to the stomach, the spleen, the intestines, and the ovaries. Our experience in the electric treatment of diseases of the lungs has not been large, but it has been sufficient to make it quite probable that certain sensitive conditions of tuberculous deposit may be suggested by abnormal sensitiveness to the faradic current over the apex of the chest.

Electro-diagnosis of the sensory nerves requires us to examine the condition not only of the various portions of the skin, but also of the nerve-branches, and the plexuses.

If in cutaneous anæsthesia we find normal sensitiveness on the nerve-branches, we judge that the disease is confined to the nerve ramifications only.

If in complete anæsthesia of an extremity the nerve plexus exhibits a normal reaction, we also judge that the disease is not central but peripheral, including the nerve-branches.

For the purpose of testing the condition of sensation the faradic current is usually to be preferred, for the reason that its mechanical effects are greater than those of the galvanic.

The electro-sensibility may be normal or nearly so when ordinary sensibility is much diminished. In some cases of posterior spinal sclerosis, for example, a moderate electric current may be fully perceptible while a pin may be thrust into the flesh without causing any pain.

The Head.—In health the head is very sensitive both to galvanization and faradization, in all parts except the posterior. This electro-sensitiveness of the frontal and parietal regions of the head is due to the superficial nerves, and not to the brain itself. In pathologic cases this sensitiveness may be either increased or diminished.

Spine.—In health the spine is but little sensitive to the current. In pathologic cases it may exhibit a sensitiveness to the electric current that is not revealed by pressure or by any other method of irritation. This condition is found in neuralgia, spinal irritation, hysteria, etc. It is interesting, also, to know that electric examination sometimes indicates abnormities in the sensitiveness of certain parts of the body that exhibit no functional derangement.*

Sympathetic and Pneumogastric.—The ganglia of the cervical sympathetic and the pneumogastric may be examined electrically by the inner border of the sterno-cleido-mastoid muscle. Sometimes there is abnormal sensitiveness all along the border of the sterno-cleido-mastoid muscle in the track of the pneumogastric. This sensitiveness is found in a large number of pathologic conditions, locomotor ataxia, muscular atrophy, various cerebral affections, etc. We have observed it also in spinal irritation, and during paroxysms of sick headache. This abnormal sensitiveness may be frequently demonstrated by mechanical pressure. We are disposed to regard this sensitiveness as due to the pneumogastric more than to the sympathetic.

Electro-Muscular Sensibility.—Electro-muscular sensibility includes a feeling of pain and a feeling of contraction. The latter may exist without the former.

Success in investigating electro-muscular sensibility depends on the condition and intelligence of the patient.

In conditions of cutaneous hyperæsthesia it is exceedingly difficult, even for the most intelligent patient, to distinguish between the sensitiveness of the skin and that of the muscle.

* Benedikt: Op. cit., p. 60.

In paralysis electro-muscular sensibility is frequently diminished, together with the electro-muscular contractility; they often rise and fall together. In hysteria, electro-muscular sensibility to pain is sometimes greatly increased. For remarks on the physiologic nature of electro-muscular sensibility, see Electro-Physiology.

Secondly. The fact that the electro-muscular contractility and irritability are more or less modified by disease.

Irritability strictly refers to the quivering which muscles exhibit under mild currents; contractility to the power of actually contracting under whatever strength of current may be necessary. The two terms are very frequently used interchangeably.

That muscular contractions can be produced by the electric currents has been known since the period of the earliest investigations in the department of electro-physiology.

The first systematic attempts to make this a basis for establishing differential diagnosis were made by Dr. Marshall Hall, and subsequently by Dr. Todd. The conclusions of these distinguished experimenters are quite familiar, and as they were unsatisfactory and partly erroneous, it is not necessary to present them in detail. More recent investigations have established that the behavior of the deep-seated muscles, in regard to their contractility, is a much more complicated question than was formerly supposed. The contractile power of a muscle is made up of two factors, viz.: the excitability of the intra-muscular nerve-fibres, and the functional capacity or irritability of the muscular substance itself. When, therefore, the contractile power of a muscle differs in any respect from the normal, this variation may be due to an abnormal condition of either one or both of these factors. Still further, it is stated that when the excitability of the intra-muscular nerve-fibres and the irritability of the muscular substances are increased, yet if the former has suffered more than the latter, the contractile power may be diminished, and *vice versa*.

In comparing healthy with diseased sides in paralysis, it is necessary to use not only the same strength of current, but also the same relative position and pressure of the electrodes.

The general principles that have thus far been established, in regard to the relation of electro-muscular contractility to disease, are as follows:

1st. In paralysis of motion the electro-muscular contractility is sometimes normal, occasionally increased, and very frequently diminished.

Increase of electro-muscular contractility, or at least of irritability, may be observed in diseases of the brain, attended with irritative lesions, in certain spasmodic and hysterical affections, occasionally in some spinal affections, as in the initial stage of locomotor ataxy, and at the outset of certain forms of peripheral paralysis. Examples of increased irritability are witnessed in rheumatic facial paralysis, in paralysis of the radial nerve from compression, and in recent neuritis. Diminution of electro-muscular contractility is usually observed in grave lesions of the anterior columns of the spinal cord, and motor tract of the brain, in rheumatic paralysis, lead palsy, in well-marked progressive muscular atrophy, and in paralysis from injury of a nerve in some part of its course.

2d. In certain central diseases the electro-muscular contractility is at first normal or diminished, and afterward increases with the progress of the disease, until it becomes greater than normal.

The length of time that is necessary to illustrate these variations depends on the nature of the disease. In chronic inflammations of the spinal cord, in effusions in the brain, causing hemiplegia, these variations may run through many weeks and months. In cases of hemiplegia also, these different conditions of the electro-muscular contractility may run in a circle; being sometimes normal, sometimes increased, and sometimes diminished (Benedikt). All these changes correspond, of course, to certain changes in the pathologic condition of the diseased brain. Just what this correspondence is in each case cannot, in the present state of electro-pathologic science, be well determined.

3d. The fact that certain forms of paralysis behave very differently under the faradic and the galvanic current. Muscles over which a faradic current can have no influence may contract easily under a milder galvanic current than is necessary to produce contractions of the same muscles in health. Sometimes, as the paralyzed muscles recover, they regain their power of contracting under the faradic current, at the same time proportionately losing their contractility under the galvanic current. This law is most readily demonstrated in peripheral facial paralysis.

This fact, that in certain peripheral paralyses galvano-muscular contractility may remain after farado-muscular contractility is wholly lost, was first pointed out by Baierlacher.

Some of the more specific principles on which electricity is used as a means of diagnosis in medicine may be thus stated. Although contractions occur only on closing or opening the current, yet we distinguish four kinds, designated by the following abbreviations: 1st, C. C. C.; 2d, A. O. C.; 3d, A. C. C.; 4th, C. O. C.

The first is the cathodal closure contraction, and occurs when the cathode, or negative pole, is applied to the nerve or muscle, and the current closed.

The second, anodal opening contraction, occurs when the anode or positive pole is applied to the nerve or muscle and the circuit opened.

The third, anodal closure contraction, occurs when the anode is applied and the current closed.

The fourth, cathodal opening contraction, occurs when the cathode is applied and the current opened.

The readiness with which these various contractions are induced relatively to each other depends altogether upon the strength of the current and the condition of the nerves, whether diseased or healthy. If on the healthy nerve or muscle the negative pole is pressed, and a current of sufficient strength employed, it will be found that on closing the circuit a contraction takes place. In order, however, to induce a contraction of the same vigor on opening the circuit, it is necessary that the strength of the current be increased. Each one can readily confirm this statement for himself, and by experimenting thoroughly it will be found that contraction in the healthy muscle occurs in the order just given.

In diseased conditions, however, this formula is subject to great variations. The readiness with which a muscle contracts to electric influences may be increased. This occurs in certain cases of hemiplegia associated with an irritative lesion; and in the early stages of facial paralysis due to the action of cold associated with a rheumatic diathesis. In these cases the intra-muscular nerves are attacked from the beginning, while there is but little if any alteration of the muscular fibres. The faradic current causes contractions through the intra-muscular nerves; therefore, in cases such as the above, its power to produce muscular contractility is lost. The galvanic current, acting more especially on the muscular fibres, retains its power, and, as experience shows, a milder current will cause contractions than is found necessary for the healthy muscle. As the patient improves, it takes an increased tension of galvanism to cause the same effects, until, finally, farado-muscular contractility becomes manifest. Again, the readiness of contraction may be decreased and finally abolished, as in the late stages of bulbar paralysis; occasionally in paralysis following acute diseases, in myelitis, and in progressive muscular atrophy.

The above are termed quantitative reactions, consisting, as has been stated, in a simple increase or diminution in the quickness of response to a current of given strength. Qualitative, which includes as well quantitative changes—in other words, termed the reaction of degeneration, "R. D."—consist in an alteration in the order of occurrence of the contractions. These changes are observed in any form of traumatic paralysis where the continuity of the nerve has been completely interrupted, in rheumatic paralysis associated with compression at some point of the nerve, in lead palsy, many forms of infantile paralysis, in spinal paralysis where the gray matter is much involved, in progressive muscular atrophy, in some cases of neuritis, bulbar paralysis, in cases of pressure on the nerve by tumors or cicatrices, etc., and in some paralyses the result of acute diseases.

The normal formula becomes, in the above cases of paralysis, subject to the following changes: The negative pole at its closure (C. C. C.) becomes as weak or even weaker than the positive (A. C. C.), and the positive pole at its opening (A. O. C.) becomes weaker than the negative at its opening (C. O. C.). At the same time the contractions become weaker and less rapid than in health. When the circuit is closed the contractions are also liable to become tetanic, while rapid interruptions of the galvanic current utterly fail to call forth any response.

Volitional Contractility may exist when Electro-Contractility is Diminished.—The volitional power may remain when the electric contractility is diminished. If a muscle exhibits diminution of contractility under electric irritation, but reacts normally to the will, the conclusion is that the muscle is not injured, but that the abnormity is caused by change in the irritability of the intra-muscular nerves. This is observed in certain stages of traumatic and lead paralysis. We arrive at the same conclusion in those cases where the muscles refuse to contract under direct, but respond normally to indirect, electrization.

Muscles of the eye are an exception to this rule, since, from their anatomic position, they cannot be made to contract by direct, but only by indirect, reflex action from the fifth pair.

Cases where reaction is lost both to the will and electricity indicate actual injury of the muscle.

Furthermore, it should be considered that the electro-muscular contractility and sensibility of diseased muscles may be and are greatly modified by the treatment, both permanently or temporarily. Modification may take place even during the *séance.*

Thirdly. That the special physiologic reactions of the central and peripheral nervous systems to the galvanic current are essentially changed when the nerve is in a pathologic condition.

This is true of the spinal cord, the motor and sensory nerves, spinal cord and nerves of special sense, and of the sympathetic. According to Benedikt, if the negative pole is placed, for example, on the peroneal nerve, and the positive on the patella, with an interrupted current, a weaker irritation appears than when the positive pole is placed on the cervical or lumbar vertebræ. The more the central parts are included in the circuit the greater the irritation. In pathologic conditions this reaction is changed.

Opening contractions are regarded by Benedikt as characteristic evidences of certain forms of locomotor ataxy. They are observed also in neuritis and in chorea minor. They indicate a molecular disturbance. They accompany both increased and diminished irritability, usually the latter.

Nerves of Special Sense.—The changes of the reaction of the nerves of special sense to electric irritation may be both quantitative and qualitative.

Auditory Nerve.—It has been shown that the reaction of the auditory nerve to galvanic irritation—the strong subjective sensations of sound—is materially changed by disease; and by this we judge of the condition of the nerve. (See Diseases of the Ear.)

Optic Nerve.—The reaction of the optic nerve under the influence of the galvanic current is attended with flashes of light. The qualitative changes in reactions of the optic nerve to electric irritation are numerous. In certain pathologic cases, as we have observed, flashes of light may be produced by the faradic current. In other pathologic cases, as severe atrophy of the retina, the flashes of light do not appear during galvanization, or only when a very strong current is used. We have observed very marked differences in the reaction of the optic nerve in the two eyes when one was diseased and the other healthy. Flashes of light from galvanization of the lower part of the spine are indicative of abnormal irritability or organic disease of the spinal cord. They are observed in locomotor ataxia and spinal irritation.

Olfactory and Gustatory Nerves.—The peculiar smell that is experienced on galvanization of the olfactory nerve may be either increased or diminished by disease. It is absent in paralysis of the olfactory nerve.

The peculiar metallic taste that follows galvanization of the tongue, or that is experienced by reflex action when the galvanic current is applied on the neck and upper part of the spine, is subject to various modifications by disease. In irritable conditions of the cord we have observed that this metallic taste will appear when the application is made in the lower part of the spine. In two striking instances it was experienced from faradization of the cilio-spinal region.

Fourth. The fact that in certain central diseases, and in conditions of great irritability, as hysteria, the reflex effect of the current is so exalted as to excite reactions that in a normal condition of the body never appear. Thus in a lady of middle life, who for several years had suffered from all the symptoms of declared chronic myelitis, we were first struck by the fact that even a very mild current over the upper portion of the back was sensitively felt down the right leg. This symptom we have never known to occur in a perfectly healthy condition of the spinal cord. Afterward we found that a very short as well as very mild application of the current to one leg caused a disagreeable feeling of pain and heaviness not only in this leg, but also in the other, for several days following the application. In another case of general paralysis dependent on hysteria, a very feeble current localized in one hand, or in one foot, would be appreciably, and oftentimes painfully, felt through all the four extremities. The patient declared that the sensation was like that of "waves rolling through the body."

A still more marked illustration of this diagnostic power of electrization was the following:

In the case of a lady whose lower limbs had been somewhat paralyzed for two years, who presented no marked symptoms of severe organic disease of the cord, we were inclined to suspect that her paraplegia might be due to nervous exhaustion, until this abnormal reflex sensitiveness to the electric current seemed to establish the existence of myelitis, or at least meningitis. We first observed that a feeble current in the neck was felt down the spine, and subsequently the patient complained that a strong current down the lower extremities transmitted pain to the back. The occurrence of this abnormal symptom forced us to the unwilling conclusion that we were dealing with a case of organic disease of the spine. The subsequent history of the case has confirmed this diagnosis. It has been shown by Benedikt,* that, in certain morbid conditions, electrization of one extremity produces contractions in the other. This phenomenon has been observed in progressive muscular atrophy, and in certain reflex neuroses. In a case of rheumatic gout that we treated the application of the galvanic current to the left knee caused a sharp pain in the corresponding part of the right knee.

This fact enables us not only to make a diagnosis of central disease, but in certain cases even to suspect the seat of the affection.

We are confident that in all cases of crossed reflex contractions—just as in the cases of crossed reflex sensation above cited—there is always some central disease. This symptom when it occurs may perhaps then be regarded as so far forth diagnostic.

Crossed reflex sensations and crossed reflex contractions may be manifested simultaneously in a patient affected with organic disease of the spinal cord. This singular coincidence was observed in the case above recorded of the lady who complained of waves of sensation all over the body when the current was applied to any one of the four extremities. These peculiar sensations were sometimes accompanied by feeble and spasmodic muscular contractions.

Diplegic Contractions.—Remak,† of Berlin, was the first to note the fact that contractions of the muscles of one or both of the upper extremities may sometimes be produced by placing the positive pole in the auriculo-maxillary fossa, just posterior to the ascending ramus of the lower jaw, and the negative by the side of the sixth cervical vertebra. The theory of Remak, that these contractions, to which he gave the name of "diplegic," were caused by irritation of the superior ganglia of the sympathetic, was apparently confirmed by Fieber,‡ by experiments on animals in whom the sympathetic was exposed, and subjected to the action of the current.

Strong currents—from twenty to forty elements—are usually, though not always, necessary to produce these contractions. The contractions may be of various degrees, from mild drawing, with scarcely perceptible oscillations, to violent movements resembling chorea. They may appear in the interossei or in the muscles of the arm or forearm of one or both sides. They may also appear in other positions of the electrode than the one described. From one to five minutes are usually necessary to excite

* "Die Elektrotherapie," p. 63.

† "Application du courant constant au traitement des neuroses," Paris, 1865.

‡ "Die diplegischen Contractionen nach Versuchen an Menschen und Thieren," Berlin, 1866, pp. 21, 22, 23.

them, and they may continue for a few moments after the application has ceased.

That these so-called diplegic contractions are a reality and not a delusion, as some have declared, we have demonstrated in a number of cases, and especially in progressive muscular atrophy. The cases where they are readily demonstrated are, according to our observation, not frequent, and we can easily see that one might practise electro-therapeutics for a long time without seeing any, especially as currents of considerable strength, applied in a certain manner, are necessary to produce them.

The evidence that these contractions occur exclusively through the sympathetic is not to our view satisfactory, and there is stronger probability that the spinal cord is the centre, which in certain irritable conditions exhibits these manifestations under strong electric stimulation. In none of the methods of application where these diplegic contractions are called forth is it possible to localize the current in the sympathetic. The special diagnostic value of these contractions is not great. They occur not only in progressive muscular atrophy, but in hysteria and hysteroid affections, and would appear to be pathognomonic of no one special disease, but rather of a condition of irritability of the nerve-centres that may appear in many different diseases.

Feigned Diseases.—By the application of the principles stated above the electric currents may be of great service in helping us to distinguish real from feigned disease. A case of pretended paralysis of motion or sensation can readily be settled by applying the current to the limb, since no force of will can fully resist the energy of the contractions that electricity may excite in healthy muscles, or the pain that can be produced by strong faradization of the skin. The principle will work both ways, and, if the electro-muscular contractility is diminished below the normal standard, we may know that the disease is real. Where one side or one limb only is affected, the comparison between the healthy portions and those where disease is suspected can easily be made. Dr. Russell Reynolds * mentions a patient with hemiplegia who was supposed to be malingering. Electrization of the limbs on both sides showed clearly a diminution of contractility on one side, as the patient represented, and accordingly the case was pronounced to be one of real hemiplegia.

Faradization as a Means of Distinguishing Real from Apparent Death—Electro-Bioscopy.—The use of electricity as a means of distinguishing real from apparent death was suggested as long ago as 1792 by Drs. Behrend and Creve. Subsequently Boer, of Vienna, used franklinic electricity on newly-born infants, and found that when muscular contractions still existed, then the child was not dead, but could be restored.

In 1852 Dr. Crimotel, of Paris, wrote a memoir in which he stated

* Lancet, April 16th, 1870.

that when farado-contractility is gone life is extinct. He stated furthermore that farado-contractility gradually disappears after death, and that after a period ranging between half an hour and two hours it entirely disappears. He suggested the term electro-bioscopy, and recommended that those who are apparently dead from drowning, syncope, apoplexy, freezing, hysteria, and the inhalation of poisonous gases, should, before burial, be tested.

Rosenthal, of Vienna, has also studied the subject with much care. He has found that both farado- and galvano-contractility gradually disappear after death. He agrees in the main with Crimotel in the following general conclusions:

Electro-contractility disappears more rapidly after death from chronic than acute diseases; it persists longer in well than in badly nourished bodies, and it usually disappears within three hours.

Rosenthal found that in amputated limbs the farado- and galvano-contractility were active the first hour, and entirely disappeared in ninety minutes. In case of drowning electro-contractility disappeared in three hours and a quarter. In some cases where rigor mortis has not appeared, where the temperature of the body is yet quite high, and where the joints are flexible, the absence of electro-contractility yet proves beyond question that the person is dead.

Rosenthal further records a very remarkable case of trance in a hysterical woman, where it was declared and believed by the physician that the patient was dead. The skin was pale and cold; the pupils contracted, and not sensitive to light; no pulse could be felt; the extremities were relaxed; melted sealing-wax dropped on the skin caused no reflex movements, and no moisture appeared on a mirror held before the mouth. Respiratory murmurs could not be heard, but a feeble intermittent sound in the cardiac region was just perceptible on auscultation. For thirty-two hours the patient had been apparently dead; but on electric examination Rosenthal found farado-contractility in the muscles both of the face and the extremities. He therefore urged the use of the faradic current to restore the patient. In twelve hours the patient recovered her speech and movements.

Two years afterward she was alive and well, and informed Rosenthal that she knew nothing about the commencement of the attack of the trance, and that afterward she heard people talk about her death, but she was powerless to help herself.

The electrode here represented (in two parts, Fig. 52) is one that we have used with much satisfaction in eliciting the various abnormal reactions that are associated with the many forms of paralysis. It will be observed that there are three binding posts at the lower extremity. The one marked *P* is to be connected with the positive pole of the apparatus; the other, marked *N*, with the negative. The third post is to be connected with an electrode applied to some indifferent part of the patient's body. The small knob marked *A*, when moved toward *P*, renders the electrode *C* positive; when moved toward *N*, the tip becomes negative. *B* is an interrupting button, which when pressed closes the circuit, and by sliding it slightly forward the circuit can be kept closed, when so desired, without effort of the operator. This form of electrode is exceedingly convenient in electro-diagnosis, from the fact that, by a simple movement of the finger of the hand that holds the electrode, the knob *A* is moved, the direction of the current instantly changed, and anodal or cathodal contraction elicited in quick succession.

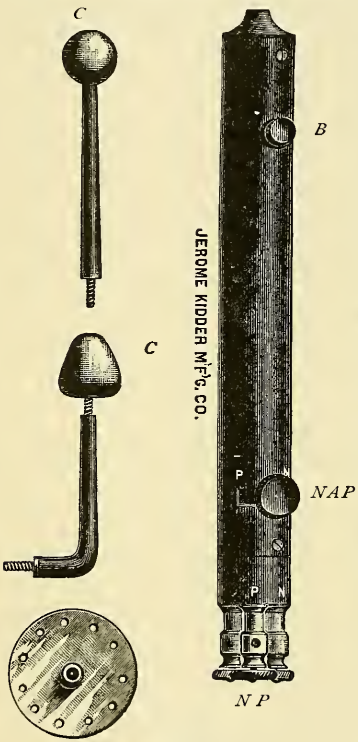

FIG. 52.
Electrode for Electro-diagnosis.

Conclusions.—The following conclusions offered by Leszynsky * are of practical value and will serve to controvert a number of popular fallacies:

1. The faradic current alone is quite sufficient for diagnostic purposes.

2. As a rule, the galvanic is supplemental to the faradic current, and in the absence of faradic irritability in nerve and muscle it is of the greatest service in prognosis.

3. The reaction of degeneration is not an essential feature in the differential diagnosis as to the location of the lesion.

4. The peripheral nerve-fibres possess an inherent power of regeneration which seems almost unlimited, the length of time required for the completion of the degenerative process varying from a few weeks to seven years or more. In severe forms of injury, therefore, the cause, degree, and character of the damage to the nerve are often of greater importance in prognosis than the demonstrations of the reactions of degeneration.

5. The presence of R. D. (reaction of degeneration) or partial R. D. is not incompatible with the preservation of motility in the same area. This paradoxical condition has been found in cases of lead poisoning, and a few others, but thus far the cause has been inexplicable.

6. Strong currents are rarely necessary. The weakest current that will produce perceptible reaction is all that is requisite.

* New York Medical Record, August 18th, 1894.

7. A decrease or disappearance of faradic irritability in nerve and muscle simply denotes an interference with the nutrition in the course of the motor tract between the multipolar cells in the anterior horn and the peripheral nerve distribution. It does not enable us to judge of the nature of the pathologic process.

8. The character of the reaction does not differ whether the lesion be situated in the cells of the anterior horn, the anterior nerve-roots, the nerve-trunks, or in their ultimate distribution. The same rule holds good in reference to the various cranial motor nerves and their nuclei, such as the facial, hypoglossal, and spinal accessory nerves.

9. When the farado-muscular irritability is lost, no reaction can be obtained by a rapidly interrupted galvanic current.

10. The secondary current from an induction coil is the one generally used in testing faradic irritability. Owing to its high electro-motive force the resistance encountered in the moistened skin may be considered negligible.

11. The difference in the poles of the faradic current is only a relative one, and cannot be determined by the usual tests as applied to the galvanic current. The electro-motive force in the secondary coil is greater at the "break" than at the "make." The electrode that is felt to be the stronger in its action is usually considered as the negative, or so-called "faradic cathode."

12. In some apparently healthy individuals the musculo-spiral nerve fails to react to strong currents applied with the "faradic anode," while a comparatively weak current from the "faradic cathode" calls forth a quick response.

13. In a case of undoubted peripheral paralysis the faradic irritability may be preserved, but it almost invariably requires a stronger current to produce muscular contractions than upon the healthy side (quantitative decrease).

14. The character of the muscular reaction demands attention. A slow and labored contraction associated with decrease in faradic irritability denotes degenerative changes.

15. The faradic irritability may return in persistent cases of peripheral paralysis without any perceptible improvement in motility.

16. Electro-diagnosis is inapplicable in paralysis of the ocular muscles.

CHAPTER VII.

ELECTRO-THERAPEUTIC ANATOMY.

Electro-therapeutic anatomy includes a description of the localities at which the different nerves, muscles, and organs can be best affected by the electric currents, and also the relative electro-sensibility of the different parts of the body. It is therefore to electro-therapeutics what surgical anatomy is to surgery.

Motor Points of Muscles.—The subject of the motor points was first systematically studied by Ziemssen, who experimented on the recently dead subject, and marked with nitrate of silver the points at which the individual nerves and muscles most readily responded to faradization. Many of these points can be easily and successfully studied on the living human subject. Those which we have represented in the cuts are derived mostly from numerous observations on persons in health. They have been found to agree in the main with those of Ziemssen, with which they have been compared, and by which they have been made more accurate and complete. Those who wish to examine the subject in greater detail are referred to the work of Ziemssen.*

It will be found, however, that those which are here described are sufficient for most of the purposes of electro-therapeutics.

The best method of verifying these points is to place one large sponge electrode, well moistened, on some indifferent point, and to firmly press a small negative † electrode, also well moistened, over the spot where the nerve or muscle should be affected. If the right place is touched, and the strength of the current and the pressure be sufficient, the normal physiologic action of the part affected will at once appear. In the case of muscles contraction will take place, accompanied with a feeling of contraction; in the case of nerve-branches and plexuses, there will be sensation more or less painful along the peripheral ramifications of the nerves, and, if the excitation be sufficiently strong, contraction of the muscles which they supply.

It is not to be understood that a studious regard for all of these elec-

* Die Electricität in der Medicin," p. 154, et seq.

† The negative is to be preferred, because it is the stronger, and acts more powerfully in producing contractions.

tric points is always necessary in making applications of electricity. In the normal condition most of the superficial and many of the deeper muscles and nerves are easily excited by ordinary labile applications with large sponge electrodes. Some of the muscles have two or more motor points, and are therefore more readily affected by large than by small electrodes.

A large sponge electrode of from 3 to 6 inches in diameter, folded over a brass ball, such as is used in general faradization, causes full contraction of a majority of the superficial and deep muscles when rapidly passed up and down the limbs.

But when the muscles have become diseased so that they respond with difficulty to the electric current, it becomes necessary to give special heed to the situation of these motor points, in order to determine their actual electric condition, or to aid in restoring them to their normal condition by exciting artificial contraction.

It should be remarked, furthermore, that these motor points vary in different individuals, just as the anatomical relation of the nerves and muscles varies, and that the representations of the cuts can be only approximately correct.

We present below a brief description of the points at which the principal nerves, plexuses, and branches can be best excited electrically, and also the physiologic effect on the nerves and muscles produced by such excitation.

Facial—at its exit from the stylo-mastoid foramen, between the mastoid process and the angle of the lower jaw, or at the opening of the external auditory canal.

Pneumogastric—at the lower and anterior part of the neck, between the common carotid artery and the jugular vein; inferior laryngeal—between the œsophagus and the trachea by the ganglia of the sympathetic.

The superior cervical ganglion of the sympathetic can be reached in the anterior maxillary fossa, just behind and below the angle of the lower jaw; the middle cervical by the side of the sterno-cleido-mastoid muscle, opposite the fifth cervical vertebra; the inferior cervical, also by the inner border of the sterno-cleido-mastoid muscle, opposite the second cervical and first dorsal vertebræ.

Accessory—at its exit from the sterno-cleido-mastoid muscle.

Hypoglossus—between the stylohyoid and hyoglossus muscles, under the hyoid bone.

Phrenic—at the outer border of the sterno-cleido-mastoid muscle, by the anterior border of the scalenus anticus, near the omohyoid muscle. Excitation of this nerve causes strong movements of the chest.

Brachial Plexus—in the supra-clavicular space, posterior to the outer border of the sterno-cleido-mastoid muscle. Excitation of this plexus causes a feeling of tingling and numbness in the fingers and down the arm, and, when the current is strong, flexion of the forearm and fingers.

Dorsalis Scapulæ—at the border of the trapezius, near the accessory.

Supra Scapularis—just before its entrance into the scapula, and external to the omohyoid muscle.

Anterior Thoracic—at the upper border of the pectoralis major, below the clavicle.

Posterior Thoracic—above the clavicle, near the trapezius.

The thoracic nerves are irregular in their distribution, and therefore difficult to find.

Axillary—at the upper and posterior border of the axilla.

Musculo-cutaneous—between the biceps and coraco-brachialis.

Median—in the lower third of the arm, at the point where it crosses the brachial artery. Mild excitation of this nerve causes tingling in the arm and fingers; a strong excitation causes closure of the fingers and pronation of the hand.

Ulnar—at the groove between the olecranon and the internal condyle. Excitation of this nerve causes pain in the inner surface of the forearm and contraction of the flexor carpi ulnaris, flexor digitorum profundus, adductor pollicis lumbricalis, and interossei of the little finger.

Radial—in the lower third of the arm, at the point of its emergence from beneath the triceps. Excitation of this nerve causes tingling in the outer part of the arm and forearm, and down to the wrist; strong excitation produces extension of the first phalanges of the fingers, extension of the hand and thumb and supination of the forearm, contractions of the extensor carpi radialis and ulnaris, extensor digitorum communis, extensor minimi digiti, extensor indicis proprius, extensor pollicis longus and brevis, adductor pollicis.

Sciatic—in the thigh, posterior to the head of the femur, at the point where the nerves issue from the pelvis, or in the pelvis, through the posterior wall of the rectum. Electrization of this nerve causes sensations of tingling in the leg below the knee, and foot, similar to those which we so often experience when we accidentally sit on the sciatic nerve.

Crural—just after its exit from beneath Poupart's ligament, exterior to the crural artery. Electrization of this nerve causes sensations in those parts of the leg that are supplied by its branches.

Obturator—on the horizontal branch of the pubic bone. If the application is successful, and the current used sufficiently strong, the thigh is abducted.

Popliteal—in the other part of the popliteal space. Electrization of this nerve causes vigorous contraction of the muscles that move the foot upward and outward.

Peroneal—on the posterior border of the capitulum fibulæ. Excitation of this nerve causes contraction of the tibialis anticus, peronei muscles, extensor digitorum communis longus, extensor digitorum communis brevis, and extensor hallucis longus.

Tibial.—This can be reached on the middle and outer part of the knee. When strongly electrized, contractions arise in the muscle of the posterior part of the leg. The tibial nerve can more easily be reached in the depression posterior to the internal malleus.

Farado-Sensibility of the Surface of the Body.—Very many muscles have no accessible motor points, and must therefore be electrized intramuscularly. Practically this is done in the majority of cases. We present in the accompanying cuts a bird's-eye view of the electric points of the prominent nerves, plexuses, and muscles, and of the relative sensitiveness of different parts of the surface of the body to the faradic current.

The relative sensitiveness of the different parts of the surface of the body to faradization, we have also ascertained by numerous comparative observations on persons in health, with the moistened hand and well-moistened sponge electrodes. The method of making these observations is to place the patient in the position for general faradization, with his feet on the plate to which the negative pole is attached, while the experimenter applies the positive all over the surface of the body.

Degrees of Farado-Sensibility.—We have distinguished five degrees of sensitiveness, the highest being marked one. For all practical purposes these are sufficient; approximate accuracy is all that is attempted. The sensitiveness of the body when irritated by the faradic current is due partly to the quality and position of the sensory nerves, and partly to the peculiar feeling that attends muscular contraction (electro-muscular sensibility).

The feeling of muscular contraction amounts in some instances to actual pain, so that a part which is not richly supplied with sensory nerves may yet be very sensitive to the current. This is especially the case with the sterno-cleido-mastoid muscle, which on being touched near its centre contracts with a painful jerk. The same is true, to a less extent, of the trapezius, the flexors of the arm, and of the peronei muscles. In all parts where no muscular contractions are produced, the sensitiveness of the surface of the body depends on the quality and position of the sensory nerves, and bears a pretty constant relation to its sensitiveness to ordinary mechanical irritation.

Thus it will be observed that the parts which are most sensitive to a blow or fall, or to any mechanical injury—as the head, face, or surface of the bones, clavicle, sternum, scapula, patella, etc.—are likewise marked highest in the scale of sensitiveness to the current.

To guard against error it is necessary—

1. To use always the same electrode and the same direction of the current; therefore the negative pole should be kept at the feet during the entire sitting.

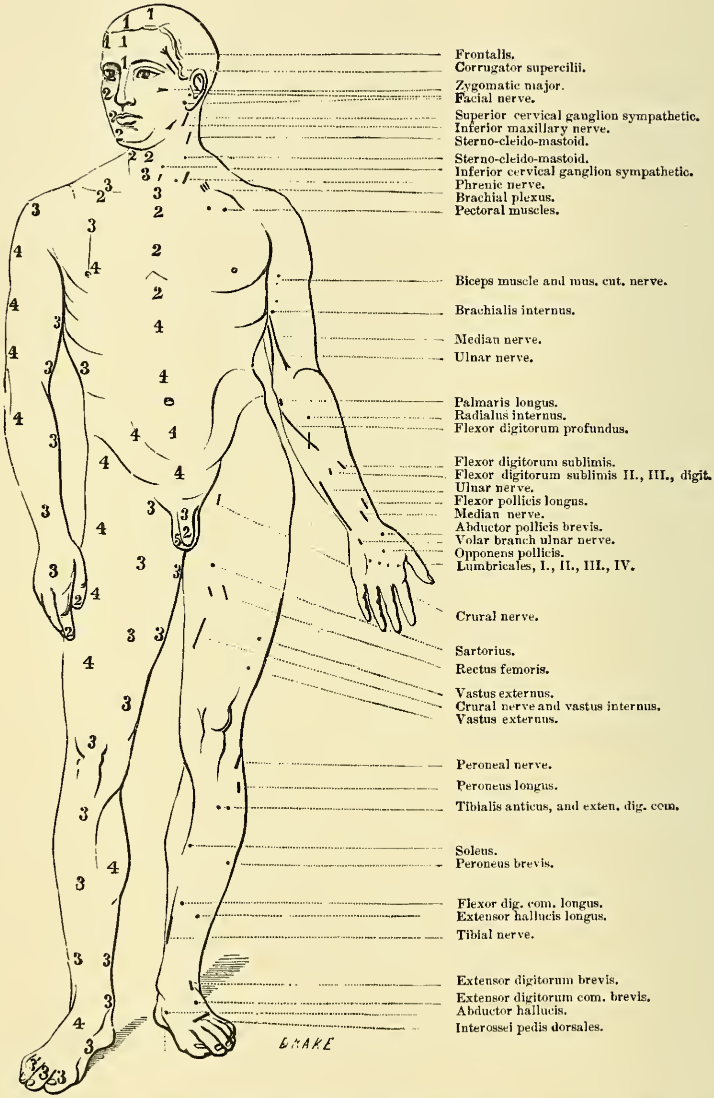

FIG. 53.—Electro-Therapeutic Anatomy of the Human Body. Anterior View. (For explanations see letter-press.)

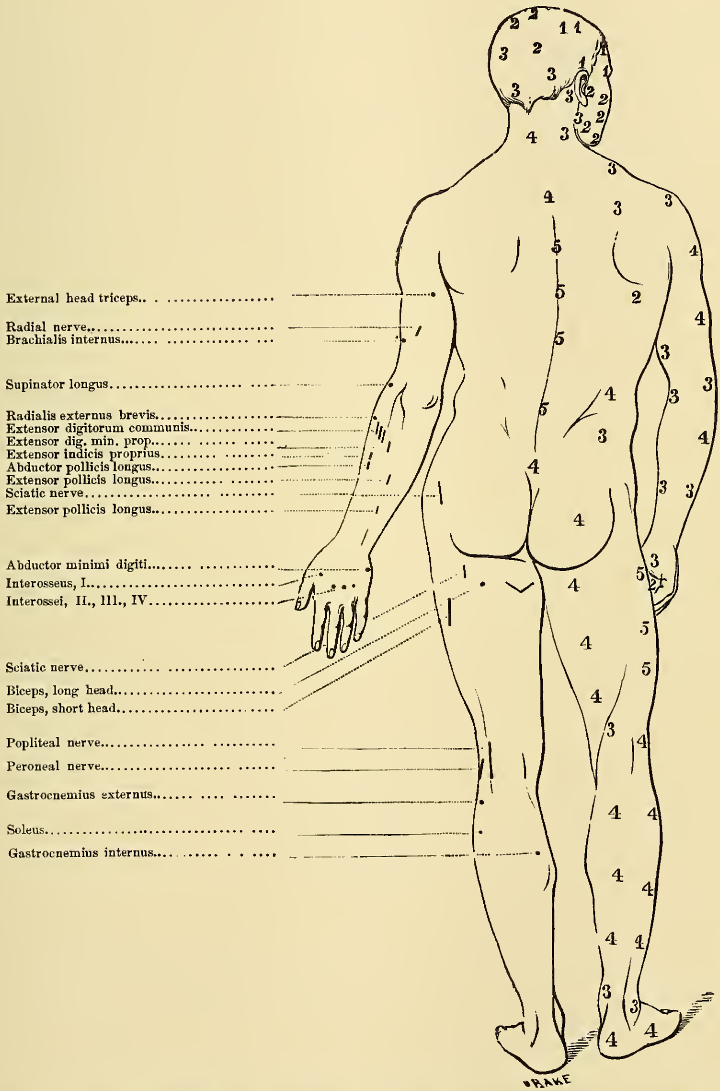

FIG. 54.—Electro-Therapeutic Anatomy of the Human Body. Posterior view. (For explanations see letter-press.)

2. To make the pressure of the electrodes uniform, and to moisten well all parts supplied with hair.

3. To use the moistened hand for the head and face. The head, especially, is so exceedingly sensitive to the faradic current that it will hardly bear a sufficient strength of current through a sponge to make a comparative estimate.

It will be observed that only a few parts are marked 5—the middle of the back, the outer surface of the thigh, and the scrotum. The perinæum, which cannot be represented in the cut, should also be marked 5. It will be observed that the points most highly sensitive are those where very sensitive nerves pass over the surfaces of bones, as the head and jaws. Of the other parts not represented in the figures, the external auditory canal should be marked 1; the middle of the sterno-cleido-mastoid muscle, 2; the axilla, 3; and the ends of all the fingers, 2; the under side of the penis, 2; the point between the penis and scrotum, 4; the under surface of the heel, the plantar arch, the ball of the foot, 4. If the external auditory canal, drum of the ear, conjunctiva, nasal mucous membrane, tongue, and larynx were represented they should be marked a degree or two higher than 1, since they are more sensitive than any portion of the surface of the head. The best point to test a current of extreme feebleness is the tip of the tongue.

The rectum, urethra, and vagina are but little sensitive to the current in comparison with the mucous membranes of the mouth, except at their external orifices. The vagina, uterus, and rectum are far less sensitive than any external portion of the body.

It should be distinctly understood that these remarks apply to the applications of the faradic current with electrodes sufficiently moistened to allow the current to pass readily through the epidermis. In dry faradization the results are somewhat different, the pain at all parts being far less.

Farado-Sensibility as Compared with Galvano-Sensibility.—The galvanic current causes a burning sensation wherever it is applied; but this is most sensitively felt at those parts that are abundantly supplied by sensory nerves. This burning feeling increases with the length of time that the current is applied.

The greater sensitiveness over bony prominences to the faradic current, as compared with the galvanic current, is due to the greater mechanical action of the former. An interrupted galvanic current, of sufficient strength to produce muscular contractions, produces the same sensations as the faradic current, with the addition of the burning feeling at the surface beneath the electrodes. The fact that the galvanic current is less painful to the surfaces of the bones gives it a certain advantage in making applications to the head, although the pain of the faradic current, when applied to the head by the moistened hand, may be reduced to a minimum.

A Knowledge of the Normal Electro-Sensibility of the Body Essential in Electro-Diagnosis and Electro-Therapeutics.—A knowledge of the relative sensitiveness of the different parts of the body to the electric current is indispensable both in electro-diagnosis and electro-therapeutics. It is at once obvious that to determine by the electric test the extent of anæsthesia, or loss of electro-muscular sensibility, in cases of paralysis, without a previous knowledge of the normal sensitiveness of the parts to the electric current and the normal feeling of electro-muscular sensibility in the affected muscles, is simply impossible. From a want of this knowledge very important mistakes are made in electro-diagnosis. In local and general faradization a knowledge of the relative sensitiveness of all the parts of the surface of the body enables one to make an application which would otherwise be painful, and perhaps injurious, both painless and refreshing.

CHAPTER VIII.

APPARATUS FOR ELECTRO-THERAPEUTICS.

THE general principles on which batteries are constructed, as well as minute description of some of the best-known elements, have already been presented in the section on electro-physics. In this chapter we propose to speak only of those combinations of elements that are used in electro-therapeutics, and our descriptions will be of a general character, having reference mainly to the practical use and care of them by the electro-therapeutist.

We can only attempt to illustrate a limited number of the numerous apparatus appliances for electro-therapeutic purposes, but before entering on their description a few general remarks may be appropriate.

1. A good battery is not all that is necessary to make a good electro-therapeutist.

There exists an impression, quite widely prevailing in the profession, that the beginning and the end of the great science of electro-therapeutics is to get a battery. This impression has wrought much evil. It has been the means of leading physicians to invest time and patience and money in a department for which they have no qualification. The purchase of a battery is simply a first step in the right direction; it is the beginning of a long road.

One who uses electricity in medicine requires good apparatus, just as the surgeon requires good instruments and the carpenter good tools; but as tools cannot make a carpenter, nor instruments a surgeon, so a battery cannot make one skilful in the therapeutic use of electricity.

2. The best and most recent apparatus is not so simple as to entirely dispense with the need of care and experience on the part of the physician.

The advance in the construction of apparatus for electro-therapeutics has been very great, but not sufficient to make it possible for faradic or galvanic apparatus to keep in order without attention.

Just as the fire in the grate goes out unless the coal is replenished, just as the gas is extinguished when the supply is shut off, so electricity generated in a battery ceases to flow unless the metals consumed in the chemic action are replaced or repaired.

The best and simplest of batteries will sometimes get out of order. Unexpected contingencies will arise that demand some knowledge of applied electro-physics. The knowledge can be obtained only by study and experience.

3. Whatever choice we make in our apparatus at the present day, we shall probably not make any very serious mistake. A few years ago it was impossible to get a really good apparatus for electro-therapeutics; now it is almost impossible to get a really bad one.

4. An apparatus to which we are accustomed is much more tractable in our hands than a far superior apparatus, the management of which is new to us. It is with batteries as with babies—every man thinks his own is the best. We see the same principle illustrated in instruments for general and special surgery.

The Separate and Continuous Coil Induction Apparatus.—There are in the market, and in common use among physicians, two quite different forms of apparatus. The first is termed a separate coil, and the second a continuous or single coil apparatus. The separate coil apparatus is the one most commonly used and the one most generally understood. The separate coil is the variety described and illustrated in every text-book of physics, but not in sufficient detail to make clear its mechanism when used for medical purposes. The accompanying diagram (Fig. 55) illustrates the course and influence of the electric current in an ordinary separate coil faradic apparatus.

All induction machines are composed of not less than two coils. The first or primary coil consists of a large, well-insulated wire surrounding a bundle of soft iron wire, which forms a magnetic centre. Over this first or primary coil is wound a coil composed of several convolutions of fine, well-insulated wire for the induced current. The terminals of the first or primary coils of wire are united, one end to the battery that operates the coil, and the other to the part of the automatic rheotome according to the following description. As the battery is the important factor, let us start from it and follow the connections and action of the combinations that produce the effect:

The positive pole (P) of the battery is connected with the governor marked A (Fig. 55). The negative pole (N) of the battery is connected with the first end of the primary coil, while the last end of the primary coil is connected with the spring support B. The electro-motive force is conveyed from the battery through the primary coil to the spring support B (rheotome), thence to the platina-pointed screw of the governor D, and lastly to the battery, making the complete circuit.

In the centre of the coil and surrounded by the soft iron wires is placed a soft iron rod. One end of the rod is bent at right angles, so that the hammer on the spring is directly over and can move toward this soft iron rod, marked C. When the vibrating spring is resting against the platina-pointed screw D and the battery is connected with the coil, the current, as it passes over the wire of this primary coil, renders magnetic both the centre bundle of soft iron wires and the soft iron rod.

The magnetism is of sufficient force to attract the soft iron hammer on the spring, and draw it down or near to the magnetized rod C.

This movement of the spring severs the connection between the spring and the platina-pointed screw D and opens the circuit. The soft iron rod, therefore, loses its magnetism. The spring ceases to be held down, its tension being sufficient to raise it to a horizontal position, where it

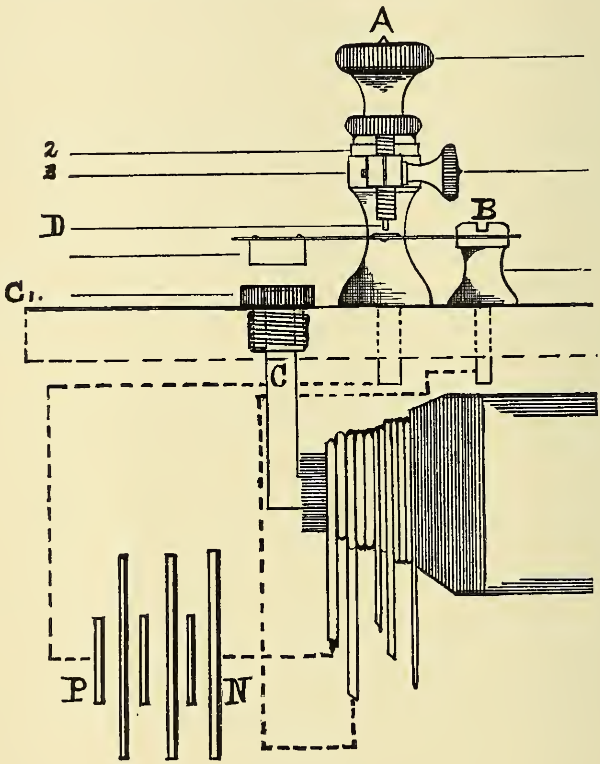

FIG. 55.

again rests in direct contact with the platina-pointed screw D. Again the circuit is closed and the process as described is repeated with inconceivable rapidity. By the action of the battery current, as it is conveyed over the primary coil, and the influence of the magnetized bundle of soft iron wires, a current is induced upon the second coil fine wire which surrounds the primary coil. This power of induction can be established to the fifth and sixth coil, and further if the magnetic field is properly arranged.

In the ordinary form of induction coil just described, the terminals of the secondary or fine wire coil are free and in no manner connected with the primary circuit. The influence of magnetism produces a current which we call pure induced.

In the continuous coil apparatus, on the contrary, we not only receive the inductive influence, but the primary influence as well, since it is carried over in combination with the induced currents. Although called a continuous coil, it is really made up of several distinct coils, and each successive coil increases in length but decreases in thickness. These coils are wound over each other, and are tapped at different portions of their length, but, unlike other forms, they make direct connection with each other. This accounts for an apparent contradiction of terms that might prove confusing.

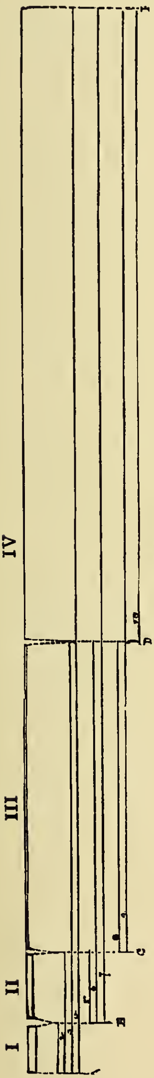

Fig. 56.

These coils (Fig. 56) are, for convenience of illustration, represented by the upper straight lines I, II, III, IV, termed, respectively, the first, second, third, and fourth induction coils. The letters A, B, C, D, E represent the different posts of the continuous coil apparatus to which the conducting cords are attached, while the numerals 1, 2, 3, 4, etc., indicate the combinations by which are obtained ten different qualities of current. The short line marked 1, starting from A, represents the current from the short, thick, first coil marked I. Second line (2), current from the first and second (I, II) induction coils combined. Third line (3), current from the first, second, and third (I, II, III) induction coils. Fourth line (4), current from the first, second, third, and fourth (I, II, III, IV) induction coils. Fifth line (5), current from the second (II) induction coil only. Sixth line (6), current from the first and second (II, III) induction coils. Seventh line (7), current from the second, third, and fourth (II, III, IV) induction coils. Eighth line (8), current from the third (III) induction coil. Ninth line (9), current from the third and fourth (III, IV) induction coils combined. Tenth line (10), current from the fourth (IV) induction coil only.*

General Rules for the Management of an Ordinary Continuous or Separate Coil Apparatus.—Minute details for its preparation for use accompany every apparatus sent out from the shops, and need not be repeated here. When the machine is ready for action, if the spring does not at

* The different physiologic and therapeutic effects of coils, yielding currents of quantity and tension, are considered in the description of bipolar faradization.

once vibrate, give it a slight stroke with the finger. If it still refuses to vibrate, it may be necessary to readjust the screw. If the spring vibrates, but irregularly or too slowly, the evil may usually be remedied by readjusting the screw.

To Distinguish the Poles.—It is always possible to distinguish the negative pole by holding the electrodes for a moment in the two hands; the one in which the current is strongest felt is the negative pole.

If the apparatus refuses to go, or if it stops at any time while in use, the cause may be looked for—

1. In the screw of the rheotome or current-breaker. This may not be properly adjusted. The point may be too far from the spring, or too closely pressed upon it. This want of proper adjustment of the screw is the most frequent cause of a stopping of the machine, and of the refusal of the spring to vibrate. The spring may sometimes be corroded at the point where the screw touches it.

2. In the connection of the wires. The wires that unite the elements may not be properly screwed at their point of connection, or may be corroded.

3. In the battery itself. The battery—that is, the zinc and platinum or carbon with the solution in the glass jar—may get out of order in four ways. First, the solution may lose its strength. This difficulty may be remedied either by pouring in some sulphuric acid or by making an entirely new solution, or by simply adding more water. Secondly, the zincs may become so corroded and incrusted as to become capable of generating a current. When we have reason to suspect that such is the case we should clean them with an old tooth-brush or cloth, or amalgamate them. When the zincs have lost their amalgam, local action may take place; this will be indicated by rapid evolution of hydrogen. Thirdly, a portion of the mercury may have fallen on to the platinum and covered it. When this happens, little or no current can be obtained. Fourthly, both the elements will in time, by hard and long usage, wear out, and will need to be replenished.

4. In the helix. It is very rarely that the helix of the apparatus ever becomes so injured as to become incapable of service. If, after we have properly adjusted the screw and spring, made sure of the connections of the wires, replenished the solution, and cleaned the zincs, the apparatus persistently refuses to go, we have reason to suspect that something may be wrong with the wires that compose the helix. If such be the case the evil can be remedied only by the inventor himself, or, at least, by some one practically familiar with the construction of helices. But we should try very patiently and perseveringly before we accept the conclusion that the helix is thus out of order, for it is an accident of extremely rare occurrence.

When no current is felt at the electrodes, although the apparatus acts properly, we know that the connection is broken somewhere in the insulated conducting wires. Sometimes the union of the wires with the electrodes is imperfect, and occasionally the wire in some part is broken. Finally, the electrodes themselves may become very much corroded, and may need cleaning before a good current can be obtained.

To Take Care of the Apparatus.—When not in use, the element wherever possible should be taken out of the solution. If the element remains too long a time in the jar an incrustation of salt will sometimes accumulate on the top of the zincs, which will need to be brushed or washed off. This salt is the sulphate of zinc, resulting from the action of the sulphuric acid on the zinc.

We may know that action is taking place in the battery when bubbles of hydrogen are rising up by the sides of the zinc.

Methods of Modifying the Current.—The strength of the current of these machines may be modified in several ways, as follows:

1. It may be modified by withdrawing or pushing in the metallic tube that covers the helix.

When this tube covers the helix an indefinite number of branch currents are induced in it that interfere with the main current and weaken it. In proportion as this is withdrawn, the induction of branch currents, and the consequent interference with the main current, grows less.

This method of modifying the strength of the current must be used continually both in general and localized faradization.

2. The current may be modified by increasing the quantity of the solution, or of the sulphuric acid in it. This measure can be resorted to when the current fails to accomplish our purpose, even when the metallic tube is entirely or nearly withdrawn.

3. When the current passes through the body of the operator, the current may be modified by increasing or diminishing the pressure of the hand on the sponge connected with the positive pole. (See General Faradization.)

The direction of the current can be changed, at any time, by reversing the position of the electrodes, or by reversing the conducting wires in the posts, or by the current-reverser, when one is attached to the machine.

The apparatus represented in Fig. 57 is among the best of those with only an ordinary length of coil. Of compact form and operated by a Tip cell much or little of the elements can be immersed at will. The current from any of the ten combinations can be selected by means of the sliding arms in the centre. The four coils of which this machine is made vary greatly in thickness and length and produce very different effects.

Another variety of the continuous coil apparatus (Fig. 58) is a model of compactness, with strength and quality of current. It is modelled after the celebrated Gaiffé battery, but is far superior in construction and strength of current. It is operated by a double, open, bisulphate of mercury cell, or can be operated by larger cells if desired. The coil is composed of four different lengths and diameters of wire, which yield a current equal in efficiency and power to batteries of much larger size. Its length is 10 inches, width 3½ inches, depth 2 inches.

Fig. 59 is a compact and valuable apparatus. It has three separate coils (coarse, medium, and fine), of varying lengths and producing effects undeniably different. The diameter and length of wire on each coil are marked in millimetres and metres. The fine and slow vibrators are both controlled by a rheostat by which the speed of both can be regulated and

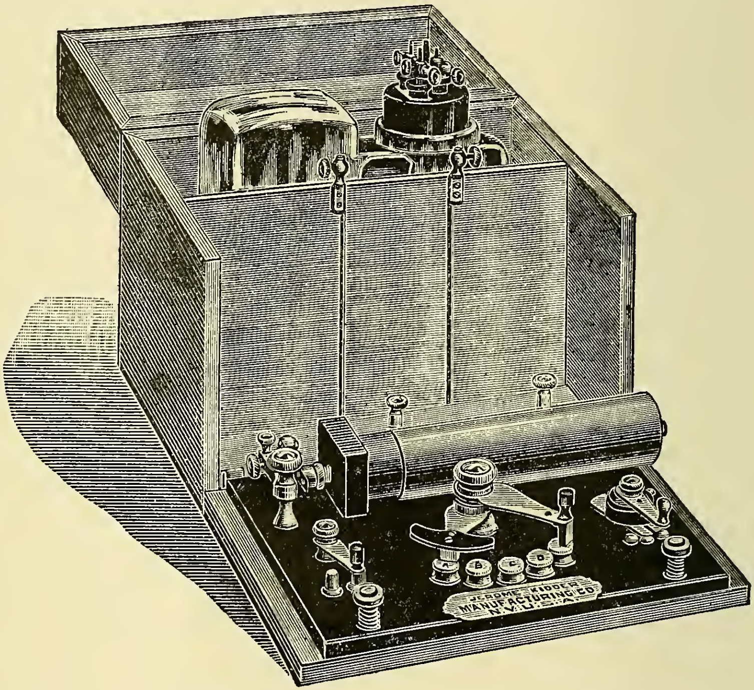

FIG. 57.—Continuous Coil Machine with Tip Battery (Kidder).

the strength of the current increased or modified at will. It has a contact key which is used for single impulses to contract a single muscle or group of muscles.

The Mier-disk rheotome in place of the ordinary spring vibrator is one of the new features claimed for the machine in Fig. 60. The interrupter is automatic, giving interruptions that vary from fifty up to many thousands per minute. Another good feature of this machine is the perfect connection of the zinc and carbon elements by which the metal work and screws are perfectly protected from the battery fluid.

Fig. 61 illustrates a combined galvanic and faradic battery. By thus combining the two the size of the case is but little increased, and this is a great convenience to those who wish to use electricity at the bedside or from house to house.

The current from the battery (Fig. 62) is generated by Leclanché

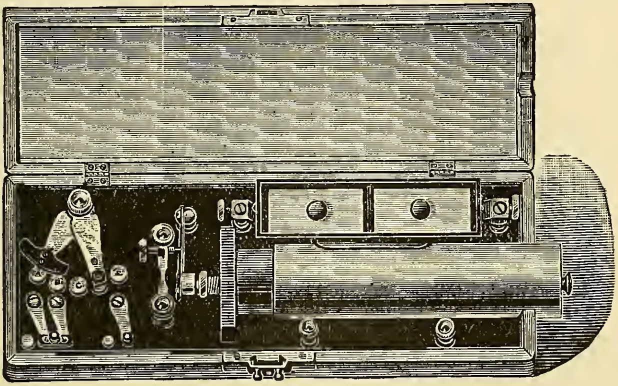

FIG. 58.—Pocket Apparatus (Kidder).

liquid cells. Each cell contains the necessary salts in dry form, and to charge the battery simply add the necessary quantity of water according to the directions accompanying each battery. The strength of the three

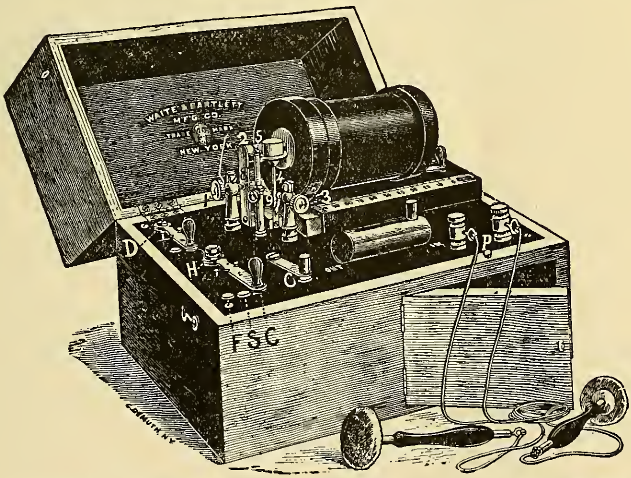

FIG. 59.—Engelmann's Faradic Battery, with High Tension Coils (Waite & Bartlett).

currents given by this machine is regulated by means of the sliding graduator attached to the front of the case.

The coil of the apparatus represented by Fig. 63 has a total length of 7,614 feet subdivided as follows:

No. 21 wire.	First division, 84 yds.	Second division	154 yds.
" 32 "	" " 300 "	" "	500 "
" 36 "	" " 500 "	" "	1,000 "

Having but one helix its advantage over the separate spool system is manifest. It is far more compact, there being no occasion to remove one spool to replace another. It possesses a far greater variety of combinations of length of wire, with the ability to increase currents of any quantity or tension from zero to the maximum effect desired. The apparatus contains a rheostat in the battery circuit, modifying the electro-motive force acting upon the primary field; a gear movement to regulate the coil over, or remove it from the primary wire; a very rapid interrupter;

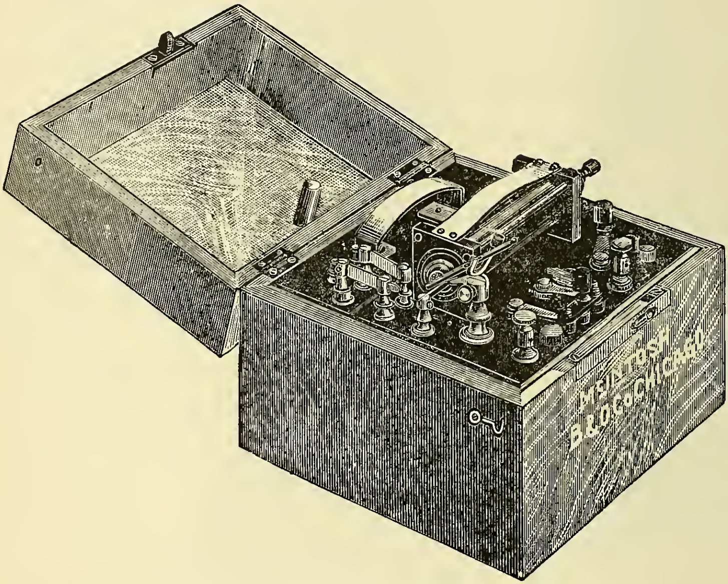

FIG. 60.—Faradic Battery (McIntosh).

slow automatic interrupter; switch for placing the same in operation; pole changer, and compound switch allowing of an instantaneous selection of wire at will. The apparatus contains four dry cells for portable work; but for office work and to get its best effects, fluid cells of a larger pattern and less tendency to polarize are essential.

Fig. 64 is a view of the right end of the coil, with the figures representing in yards the length of the different combinations. The different sizes of the wires, Nos. 21, 32, and 36, are also designated. The various sections of wire can be selected by placing the two arms upon any two buttons, and whatever buttons the arms are placed upon, the length and sizes of wire as stamped between the buttons will be included in the circuit.

With this compound circle switch one can readily select the entire coil with its varying sizes and length of 7,700 feet, or the last section or any intermediate section. A study of this compound circle switch will show that there are twenty-one possible combinations, equalling an apparatus having twenty-one separate spools.

Although these different currents are distinctive, it is not to be supposed that they all differ materially in their physical or therapeutic effects, or that the differential indications for the use of the majority of the combinations are of importance. For all practical purposes three or four coils are all that one can possibly be called upon to distinguish between.

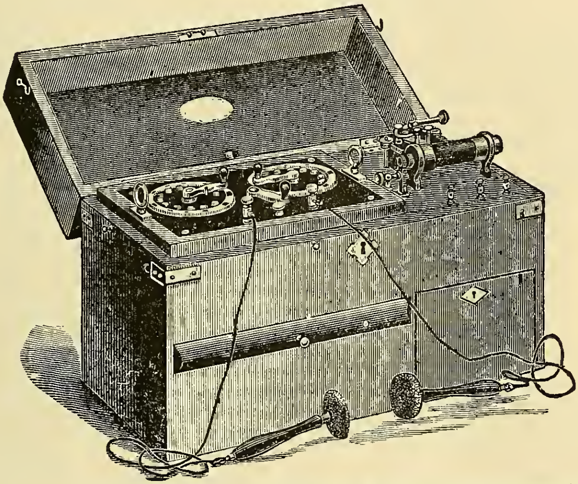

FIG. 61.—24-Cell Combined Galvanic and Faradic Battery (Galvano-Faradic Mfg. Co.)

In Fig. 65 we have represented the various sizes and lengths of wire in the high-tension coil:

The heavy lines represent No. 21 wire, subdivided, first section 84 yards, second section 154 yards; total, 238 yards.

The medium lines represent No. 32 wire, subdivided, first section 300 yards, second section 500 yards; total, 800 yards.

The fine lines represent No. 36 wire, subdivided, first section 500 yards, second section 1,000 yards; total, 1,500 yards.

The round circles represent the terminal buttons (seen in Fig. 64) over which the compound switch arms pass, selecting the various lengths of wire. In this apparatus there are nearly 16,000 magnetic lines of force.

Fine wire, high tension, and rapid vibration are the three factors which produce the special and sedative effects of the present and all improved high-tension apparatus. In order that the physician may be able to determine for himself whether any given coil fulfils the requirements of high tension a practical test is necessary, and one that may be applied by every physician to his own battery.

Such a test is afforded by the Geissler vacuum tube. Select a moderate size tube, and place it in the secondary circuit. Pass the current through an ordinary coil, and no effect within the tube will be produced.

It requires about 4,000 feet of No. 36 copper wire to create tension enough to glow the tube. Without sufficient tension, therefore, to glow the tube a coil cannot be considered a high-tension coil. With a coil,

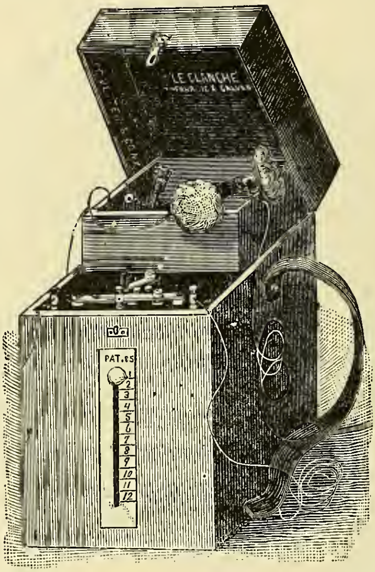

FIG. 62.—Vetter-Leclanché Faradic Battery.

however, containing 6,000 or 8,000 feet of properly wound wire we obtain a beautiful effect within the vacuum tube and demonstrate the existence of high tension in fact.

The lumen of the tube is seen filled with luminous disks like rouleaux or corpuscles in active agitation. As they lean slightly in the direction of the current flow and reverse with each change of polarity they indicate that this is not an alternating current, but is a flow in one direction, interrupted, but not alternating. The polarity is also determined in another way. The bulb at the positive end is clear, while the negative bulb is filled with mist.

Galvanic Apparatus.—Unlike the faradic current, which varies immensely according to the character of the coil and the voltage behind it, the galvanic current is the same however generated, and therefore in the selection of a galvanic there does not exist the same necessity for care as in the selection of a faradic apparatus.

It is not so much a question of quality of current as questions of portability, rapidity of polarizations, accessories, solidity of construction, and general convenience.

Hydrostat.—In the ordinary zinc-carbon fluid battery the hydrostat is an excellent contrivance for keeping the fluid from spilling, when the bat-

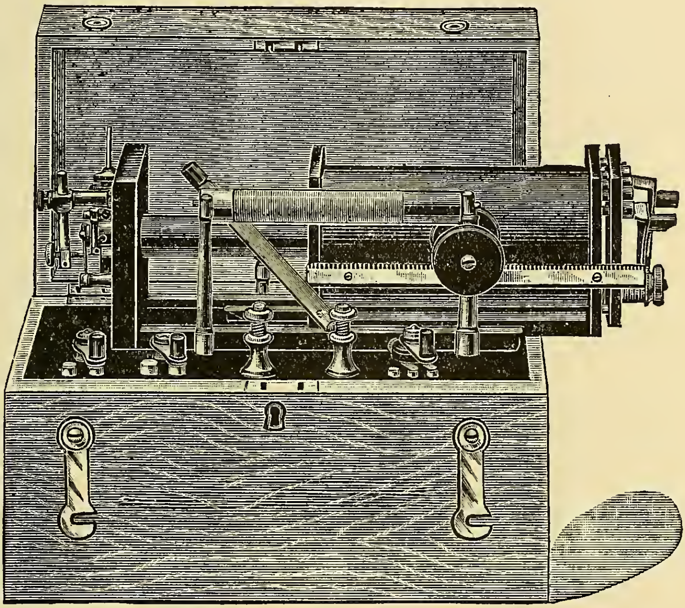

FIG. 63.—High-Tension Apparatus (Kidder).

tery is carried in a buggy or on a long journey. It consists of a rubber covering accurately fitted on the top of the cells.

Practical Directions for the Use of Zinc-Carbon Cells.—The following directions will substantially apply to all or nearly all forms of the zinc-carbon battery, by whomsoever manufactured.

How to Charge the Cells.—The solution is made in about the following proportions: sulphuric acid, 1 oz.; bichromate potass, 1½ oz.; water, 10 oz. The best way to make the solution is to dissolve the bichromate of potash in cold water and then add the sulphuric acid. The mingling of the water and sulphuric acid causes great heat. Do not use the solution until it is cool. We had not been able to get any satisfactory explanation of the fact that solutions when hot injure the battery until it was found from experiment that when the bichromate of potash solution is used hot a layer of ozone is formed on the carbon; this at once weakens the current.

Lift out the plates by the middle piece to which they are attached, lift up the jars by the keys, and fill each jar with two, or three, or three and a half ounces of the solution. They should be filled pretty uniformly, and care should be taken that no more should be put in than the jars will hold after the plates are immersed.

How to Clean the Battery and Amalgamate the Zincs.—Every few weeks or months, according to the extent to which the battery is used, it will be necessary to wash the plates and scrape off the exudation and renew the solution, or, at least, to add more acid or water, and amalgamate the zinc. The chrome alum that collects in the bottom of the jars and becomes very hard can be softened by allowing warm water to stand in the jars for a time, and then loosening the deposit with any sharp instrument. A

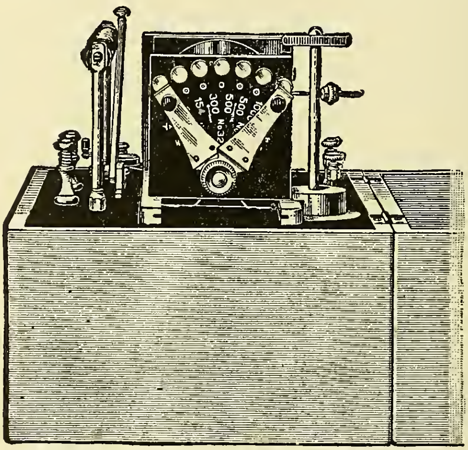

FIG. 64.—Right End of High-Tension Coil.

good way to amalgamate the zincs is, take a strip of zinc, dip it in a solution of sulphuric acid and water, then dip it in mercury; the mercury will adhere to and run over it; then rub up over the surface of the zincs of the battery until all are well covered with mercury. During the process of amalgamation the zincs should be kept well moistened with a solution of sulphuric acid and water.

Fig. 66 shows a convenient form of portable galvanic battery with the door open, illustrating the construction of its various parts. The box contains a compartment at the bottom into which the hydrostat board H is put when not in use. When the battery is to be carried about this board H is placed on the top of the cells, with its rubber padded side down. The plug and socket arrangement is simply another method of increasing the strength of current gradually, cell by cell, without shock.

The portable dry galvanic battery (Fig. 67) is run by a modification of the Leclanché cell which yields a fairly high electro-motive force, has a low internal resistance with the great recuperative power of this well-known cell. The cells are connected in series, and the two terminals of the series are connected with the Vetter carbon current-controller, which is mounted on the top of the case. The average life of these cells is from one to three years, according to use, and the current is steady and constant. The Barrett is another excellent dry-cell apparatus, readily portable and of remarkable constancy.

The exciting elements are zinc and chloride of silver, and it gives eight hundred hours of work before it is exhausted.

Fig. 68 represents a very complete keyboard through which can be operated cells of any description. The Law cell is mostly used with this contrivance, and they give a most constant, uniform, and steady current.

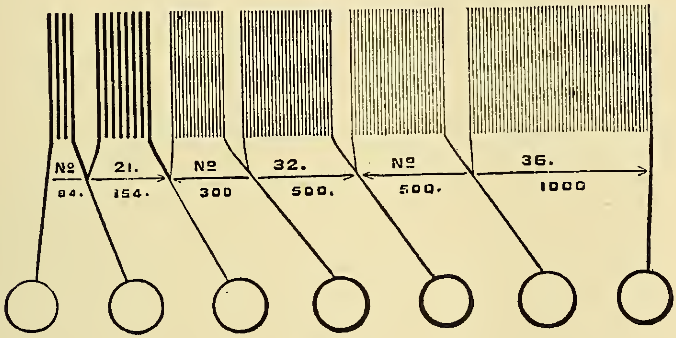

Fig. 65.

This advantage it shares with all the various constant batteries. The explanation of the constancy and steadiness of the current from these combinations of the Law cell is found in the fact that on account of the feebleness of the solution the chemic action is slow and uniform, with no interruptions or even variations.

The cabinet battery (Fig. 69) is furnished with forty or more cells of the "Fitch Perfect Battery." The galvanic circles, with double-cell selectors, wire coil rheostat, pole changer, automatic rheotome, and the various switches to bring into circuit the milliammeter, automatic rheotome, and water rheostat, are mounted on a vertical base, and the faradic coils of high tension, water rheostat, and the binding posts are placed on a horizontal base of polished hard rubber. The cells are arranged on shelves in the lower part of the cabinet, doors being provided so that they are easy of access. Heavy insulated copper wires connect the cells with the buttons within the circles on the base, the wires passing up at the back of the cabinet, which may be opened and expose the connections to view. The double-cell selectors allow the operator to select any cell or cells within the circles, and to use them uniformly.

They are provided with broad flange bottoms, and, when selecting additional cells, these slide from one button to another, always resting on one before leaving the other, so that a gradual increase of the current is insured without the possibility of a shock. The rheostat has German silver wire coils of from 5 to 5,000 ohms' resistance, a total resistance of 17,000 ohms, and may be used in connection with the meter to measure the resistance of the patient or to test the condition of the cells. The meter is a vertical form, which is unaffected by magnetic influences, and therefore does not have to be adjusted. It has a scale of double values, and measures from one to five hundred milliamperes. This is placed on a bracket in the top of the cabinet, and is easily read from a distance. The automatic rheotome gives graduated interruptions of the galvanic

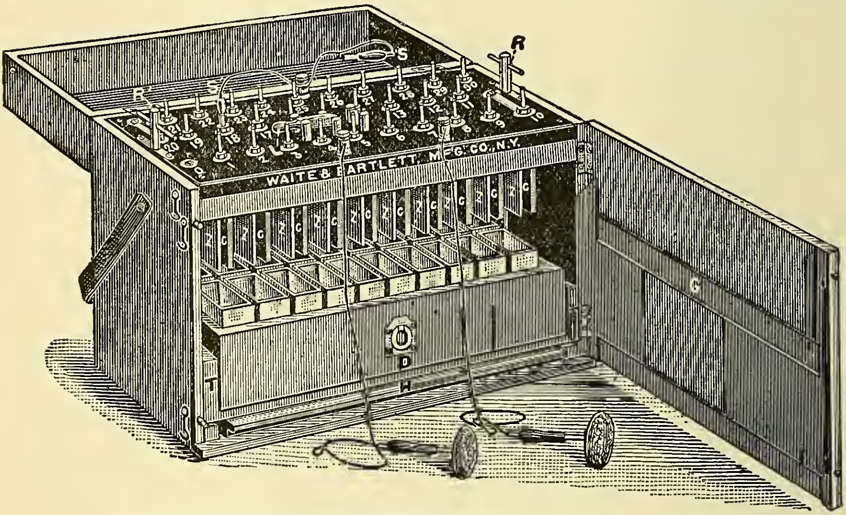

FIG. 66.—Plug and Socket Galvanic Battery (Waite & Bartlett).

current. It is constructed on the principle of a clock, and is operated by a strong spring that is not liable to get out of order.

The water rheostat may be used to gradually modify the current from any series of cells.

For the use of the 110 or 120 volt direct current the Kennelly adapter (Fig. 70) is a very complete, compact, and satisfactory apparatus. It consists of a hard-rubber cylinder, upon which is wound in suitable grooves, cut on the face of the same, several hundred feet of German silver wire, having a very high resistance.

Near the end of the cylinder on the left, very high resistance carbon blocks are introduced into the circuit, making the total resistance about 33,000 ohms. This rheostat is regulated by the sliding contact which travels along the two rods above and parallel with the cylinder.

A 16 C. P. lamp is placed in circuit with each of the leading-in wires to effectually protect the patient and apparatus, should a short circuit occur on any part of the electric-light circuit.

A third lamp, shown on the extreme right, provided with a key, is arranged in shunt with the rheostat. When the key is turned on, the voltage of the galvanic current is reduced to 60 volts. With this shunt in operation, and all the resistance of the rheostat thrown into the circuit, by moving the sliding contact to the extreme left, a current of one milliampere is obtained when the binding posts are connected together by a short piece of wire, *i.e.*, short-circuited. On moving the sliding contact to

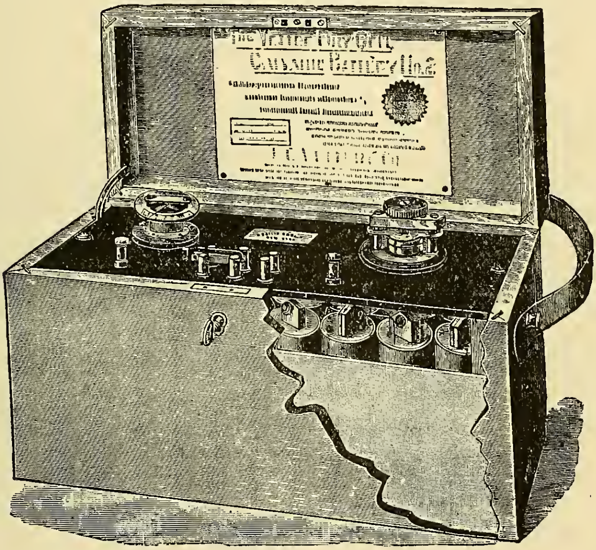

FIG. 67.—Portable Dry Galvanic Battery (Vetter).

the right, the resistance is very gradually diminished, and the current correspondingly increased. This finely graduated current is required in some cases, where a very slight irregularity in the current would produce a shock to the patient.

When a stronger current is required, the lamp is cut out by turning off the key and the current is used unshunted.

The Kennelly milliammeter is mounted on the base on the left, the pole-changing switch is placed in the middle of the board, while on the right is shown the faradic coil, which is also operated by the street current.

The converters or adapters of McIntosh, Vetter, and others are all practical and efficient.

In Fig. 71 is illustrated a method of employing the constant incandescent current for cataphoresis, electrolysis, and the ordinary purposes of the galvanic current. In the use of the four devices here illustrated we combine scientific accuracy with perfect safety. We have:

1. The Vetter current-adapter, which is inserted into the light socket and brings the 16 C. P. lamp in series, thus limiting the current capacity to ½ ampere.

2. The volt-controller, by means of which any desired voltage from 1 to 110 can be selected.

3. The carbon current-controller, which controls the current thus obtained in the finest gradations, to the fraction of a milliampere.

4. The Standard milliammeter, which is absolute in its reading and shows the exact amount of current passing.

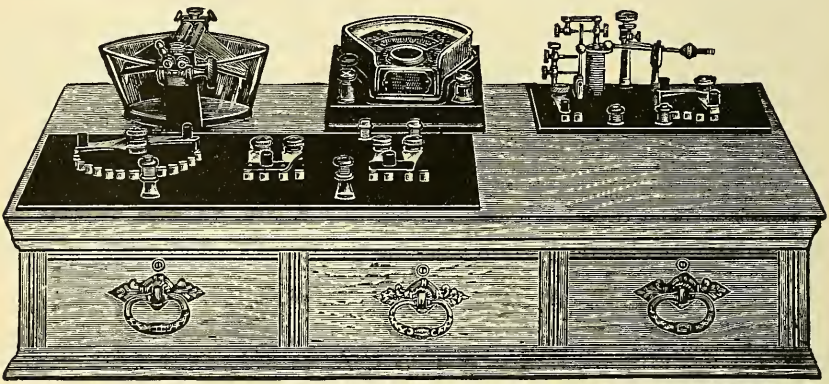

FIG. 68.—Keyboard of Cabinet Battery (Kidder).

Sinusoidal Apparatus.—The sinusoidal is an alternating current having a special character and taking its name from the fact that in its relation to time it follows the law of sines. When graphically represented we see a curve sinuous in form and far less abrupt than those of the ordinary faradic apparatus. Its motor effects vary according to the rate of its alternation. If they are slow—twenty or less a second—clonic contractions are elicited at each alternation.

Up to two or three thousand alternations the pulsations are still distinct, although the muscular contractions become tetanic.

Above 12,000 per minute a current is obtained producing some of the effects of the galvanic. Its quantitative effects on degenerate muscular fibre are more marked than in the use of the faradic current—especially if the machine generating the current is arranged for quantity. Dr. J. H. Kellogg, who has experimented largely with this current, ascribes as the reason for its peculiar motor effects the excitation of strong muscular contractions without affecting the cutaneous nerves or nerves of ordinary sensation to, first, the sinusoidal character of the curve produced by it, which represents the gradual and uniform increase of the current from zero to maximum and back to zero again, first in one direction and then in the other; and, second, the interesting fact developed by laboratory experiments in electro-physiology, that electric applications produce a state of hyperexcitability in the region of the anode the instant the current ceases to flow.*

An apparatus for the production of the sinusoidal current is illustrated in Fig. 72. The alternator on the top of the table to the right is driven by a small motor running on the Edison direct 120-volt current (shown on left). The field frame is of laminated iron supported by castings, and has twelve poles. On each pole is a spool with two windings of wire. The inner has eight layers of fine wire, and the outer two layers of coarse.

All the fine wire windings are connected in one series, which constitutes the secondary or delivery coil. All the coarse wire windings are connected in another series, forming the primary or field winding of the machine. By this arrangement it is only necessary to drive the armature, which is a combination of laminated iron disks, to transform the continuous primary current into alternating current waves in the secondary circuit, and by duly proportioning the grooves and projections on the armature surface, these waves are made sinusoidal.

Twenty-four alternations or twelve complete periods are generated for every revolution of the armature, and since a speed of 4,800 revolutions per minute can be attained, the frequency can be carried to 1,920 alternations per second, or over 115,000 alternations per minute. For steady running a more moderate speed and frequency will unsually be desirable.

The primary winding of the alternator is excited by the 120 volt direct current, which is controlled by a lamp rheostat, the switchboard operating it being shown in the front of cut on the right and the lamps being placed under the table. In this way the strength of the secondary currents can be controlled independently of the frequency.

The speed of the motor, and consequently the number of alternations of the secondary currents, can be varied by the lamp rheostat shown in the front of cut on the left, as this rheostat is included in the motor circuit.

The rheostat shown in the centre of the table is connected in shunt with the secondary circuit, and is used to vary the strength of the current applied to the patient.

Another apparatus for the generation of the sinusoidal current is seen in Fig. 73. It differs from Kennelly's in that the shaft upon which the armature of the sinusoidal apparatus is wound is directly attached to the shaft of the motor, thus doing away with the inconvenience of a belt. By

* Transactions American Electro-Therapeutic Association, 1894.

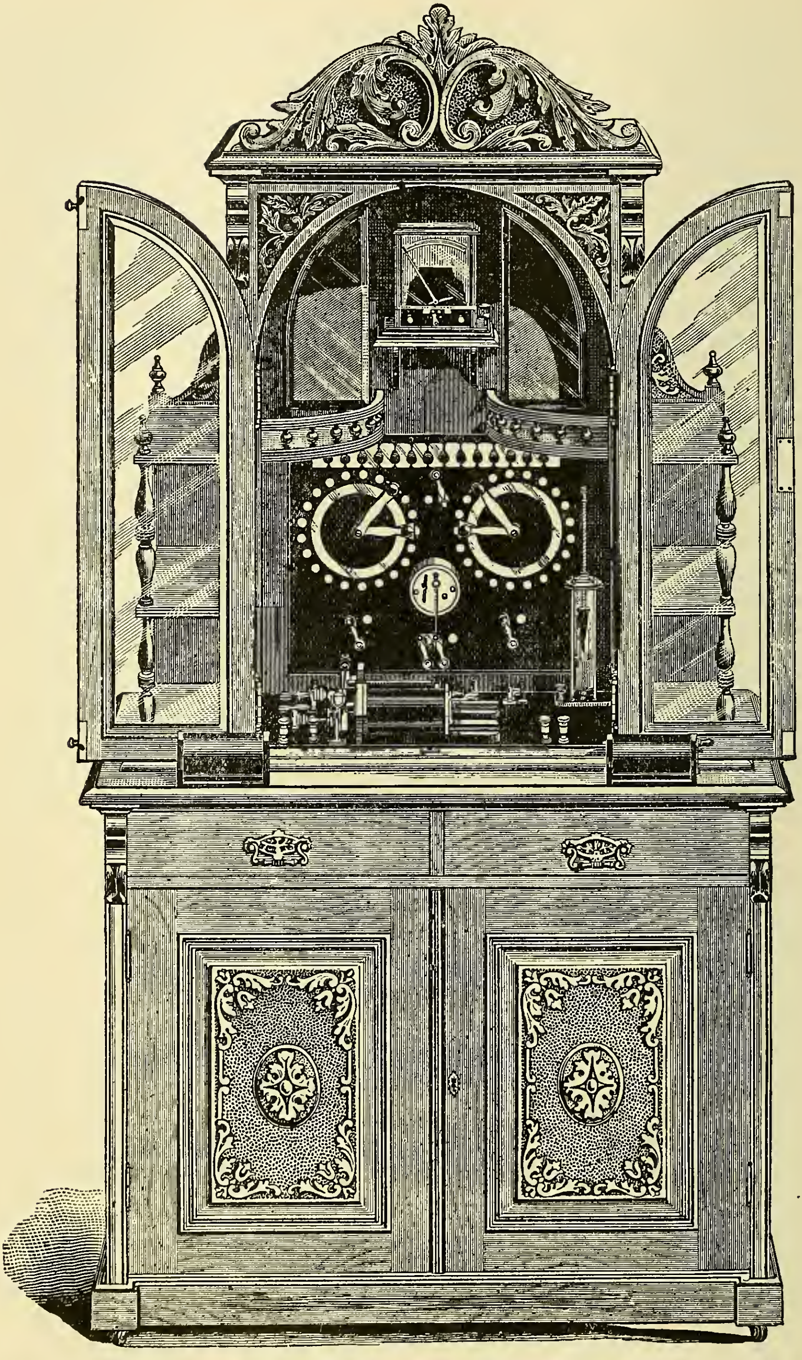

FIG. 69.—Cabinet Battery with High-Tension Coil and Wire Rheostat (Van Houten & Ten Broeck).

means of two extra brushes the current from the machine is commutated into a direct, or rather an interrupted, galvanic current, which is interrupted into the patient's circuit by means of a switch by which the operator may at will change the current from alternating to direct.

Rheostats.—The general object and principle of the rheostat has been already described. It remains here to speak of those forms that are best adapted for electro-therapeutics.

A form of rheostat very well known to electro-physiologists and electro-therapeutists is that of Siemens, and introduced into electro-therapeutics by Brenner in his researches on the ear. The unit of Siemens is a

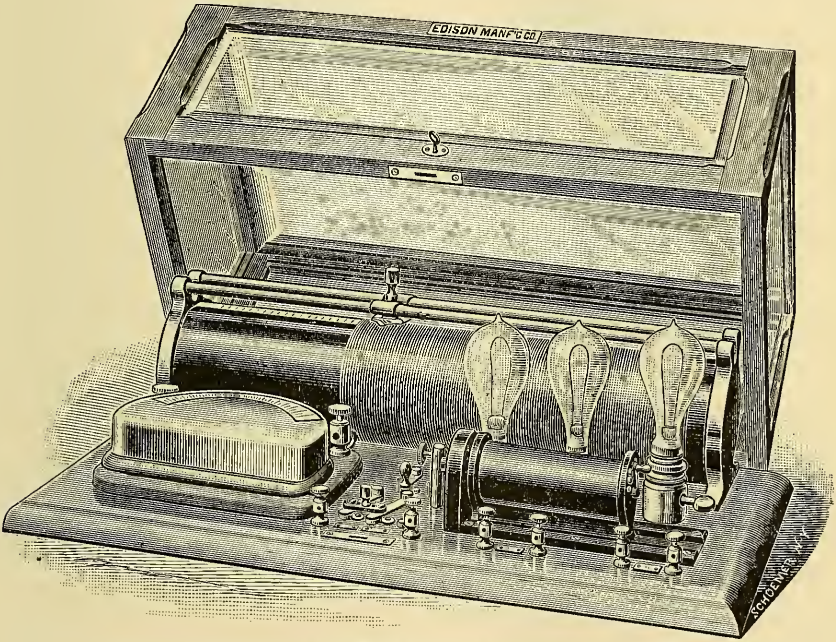

FIG. 70.—Galvanic and Faradic Adapter (Kennelly's). (For use on 110 or 120 volt circuit.)

column of mercury, one metre long, with a transverse section of one square millimetre, at 32° F.

Hydro-Rheostat or Carbon-Rheostat.—For all the practical purposes of electro-therapeutics, even for the most delicate applications to the most delicate organs, as the ear, eye, etc., the common water rheostat or the carbon rheostat are sufficiently precise, and in convenience are incomparably superior to the stopper rheostats. But for the measurement of the resistance in ohms the more modern instruments are constructed of German silver wire for the reason that its resistance is affected but slightly by changes of temperature. Wire stopper rheostats, however—

although useful in enabling the physician at once to inform himself of the varying degrees of resistance in ohms of the human body—are for general purposes of utility of no more value than the simpler forms to be described.

The water rheostat (Fig. 74), represented in the cut, is simply a column of water, interposed in the circuit, and so arranged that the distances between the extremities of the carbons that close the circuit through the water can be increased or diminished at pleasure.

This instrument consists of two triangular-shaped carbon plates, each carrying a bit of sponge at one of its angles, and so mounted over a small

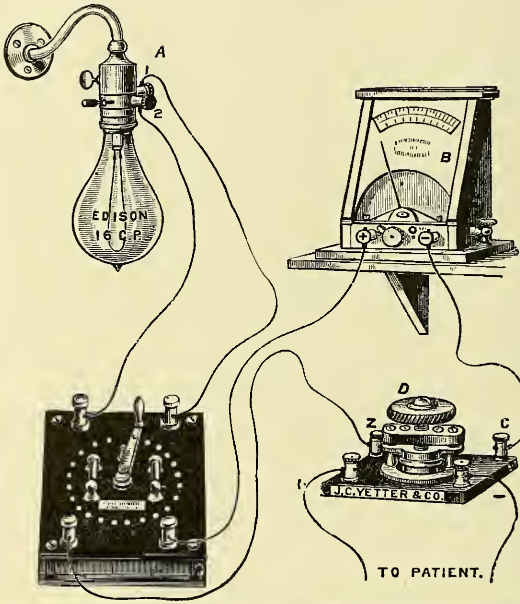

FIG. 71.—Volt Controller for Incandescent Current (Vetter).

glass cup of water that, by means of a worm gear operated by a hand-wheel, the sponge tips are gradually moved down into the water and toward each other until the plates touch at their lower points. It will give a feeble current at the outset and will increase the current without variation or fluctuation, and finally will give the full strength of the battery without shock.

A rheostat of some form, though not always indispensable in electric applications, is yet a great convenience, especially in central galvanization, in local galvanization of the nerve-centres, and in all internal and electrolytic methods of treatment where strong currents are used it is a necessity.

The advantage of this and various other forms of dry-current controllers (Fig. 75) that have been suggested lies in the possibility of utilizing the whole strength of one's battery. The mechanical principle of this particular rheostat is that of the letter-press, and one of its advantages lies in the possibility of utilizing the whole strength of one's battery. A quantity of carbon in a finely divided state is placed in a small rubber cylinder which is between two metal plates, forming opposite ends of a circuit. By turning the knob "on" or "off" as marked, thereby compressing or relaxing the granular carbon contained in the rubber pouch,

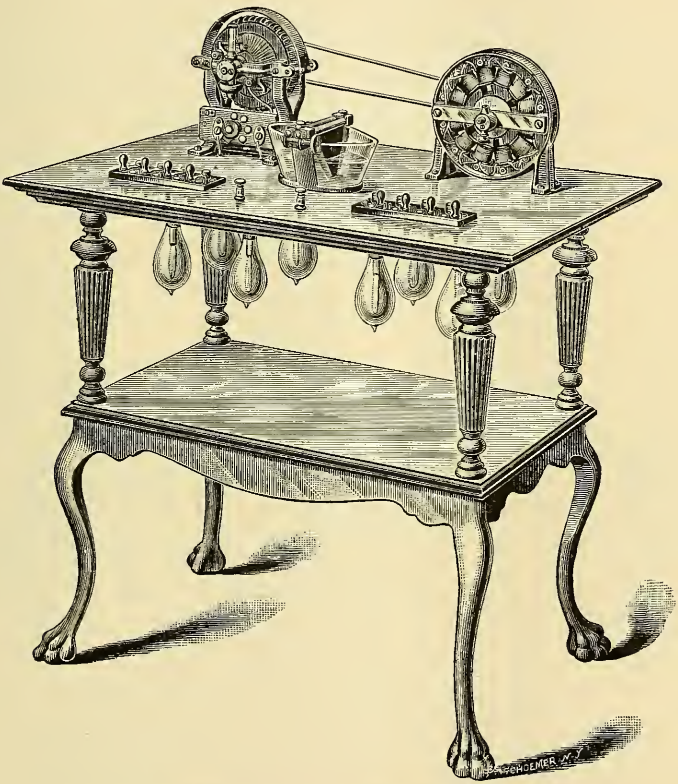

FIG. 72.—The Kennelly Sinusoidal Machine (Edison Mfg. Co.).

the current can be increased or decreased at pleasure. The absence of liquids and the non-corrosibility of the material that offers the resistance is a decided advantage.

The Monell rheostat (Fig. 76), the first to be successfully applied to dose regulation and registration of secondary coil currents, consists of two parallel tubes fixed upon a base and containing a resisting fluid of definite and permanent composition, through which a movable rod is raised or lowered by the operator. Tube No. 1 is given a high resistance to control high-tension currents of great power. Tube No. 2 has a much lower resistance for currents of less penetrative energy. The rheostat may be operated in the secondary circuit of any high-grade induction apparatus to which suitable connections are attached.

No claim is made that the rheostat is a faradic meter, but it is calibrated in ohms of resistance that admit of accurate registration of the dose administered at any given time.

There is an existing need for a standard method of recording the treatment administered, and thus imparting a uniform and intelligible value to the reports of clinical cases, now so lacking in precision and definiteness. The method suggested by Monell is a practical one. To record the current strength of any application, he takes the value represented by the resistance cut out of his calibrated rheostat.

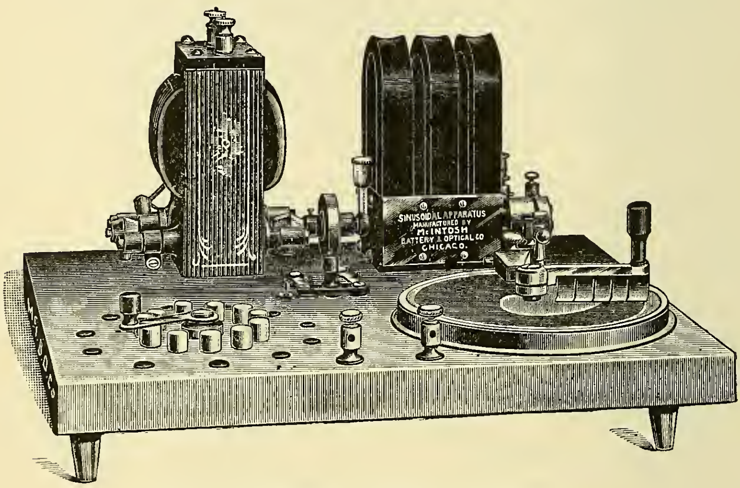

FIG. 73.—Sinusoidal Apparatus (McIntosh).

Milliammeters.—What the compass is to the mariner the milliammeter is to the electro-therapeutist. Without it he would often find himself quite at sea, and would be liable either to get no results or, in cases especially of internal treatment, when the resistance is low, accomplish far more harm than good. The meter Fig. 77 is a good one, having been calibrated with great care and from standard electric test sets. The scale indicated by the lower figures gives the low reading of milliamperes, by fraction of milliampere. The upper scale gives the higher milliampere readings. The instrument is sensitive and the pointer will oscillate quite freely, but it is supplied with a dead-beat attachment, so that the pointer can be immediately brought to rest by pressing the knob.

It is of a type similar to the Weston & Kennelly meters, and is practically unaffected by outside magnetism.

The vertical form of milliammeter (Fig. 78) is, because of its convenience, preferred by many from the fact that it is easier to read from a

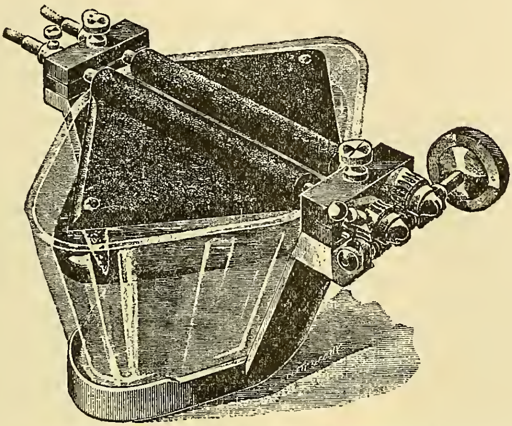

FIG. 74.—The Bailey Hydro-Rheostat (Van Houten & Ten Broeck).

vertical scale than from a horizontal one. The lower scale is from 0 to 50, and the upper scale from 0 to 500, the change from one scale to the other being quickly made by moving the switch shown in the front of the cut.

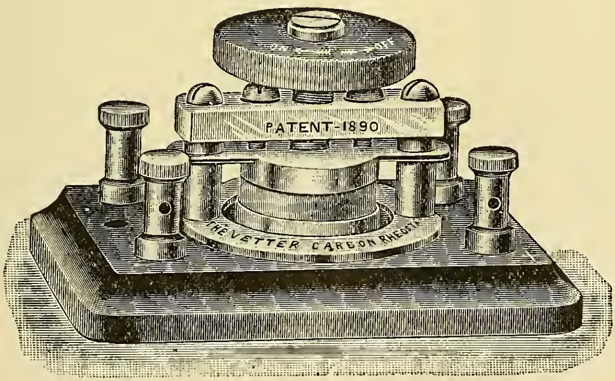

FIG. 75.—The Carbon Rheostat (Vetter).

The Weston instrument is more expensive, but is regarded as standard and perfectly accurate; the Kennelly is also known as an instrument first-class in every respect. Others that give good satisfaction are the Vetter, Waite & Bartlett, Queen & Gaiffé, etc.

Electrodes.—There are so many forms of electrodes manufactured and in general use that it will be impossible and, indeed, unnecessary, to do more than to indicate a few that are practically useful. Special forms of electrodes will be found described in connection with the conditions for which they are used.

The graduated electrodes (Fig. 79) to be attached to the universal handle (Fig. 80) are very convenient in practice. Covered with fine sponge or absorbent cotton, one has readily at hand in compact form any size of electrode for diagnostic or therapeutic purposes.

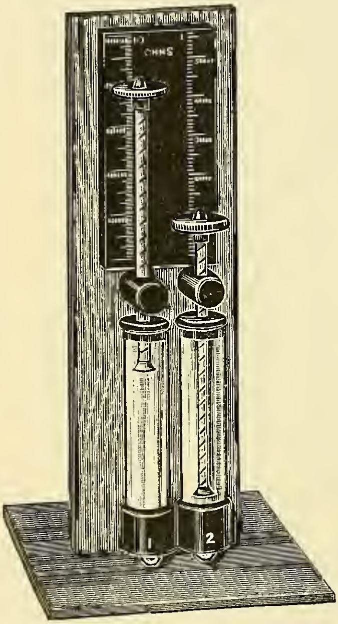

FIG. 76. — The Monell Rheostat for Dose Registration of the Faradic Current (Kidder).

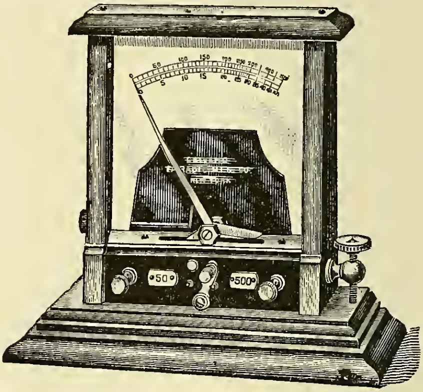

FIG. 78.—Vertical Milliammeter (Galvano-Faradic Co.)

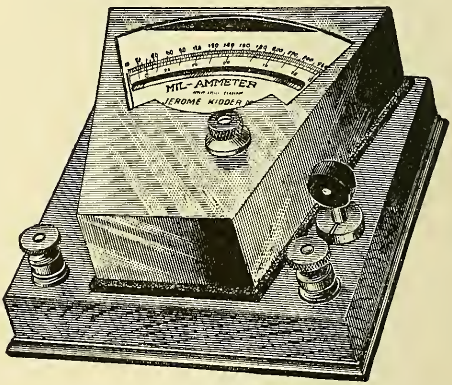

FIG. 77.—Milliammeter (Kidder).

To fix the sponge on the holder, unscrew the handle B (Fig. 81) by turning the handle itself. Place the sponge on the outer surface of the lower plate D, and bring the edges of the sponge over the edges of the plate, clasp it with the plate C, and hold all together by screwing on the handle B.

Fig. 83 represents a foot plate for general faradization. It is an improvement on the simple metal plate, because of its movable flannel cover, insulated on one side with soft rubber to prevent wetting and soiling the carpet.

A large, soft sponge, loosely folded about the ball (Fig. 84) makes the most convenient possible electrode for general faradization.

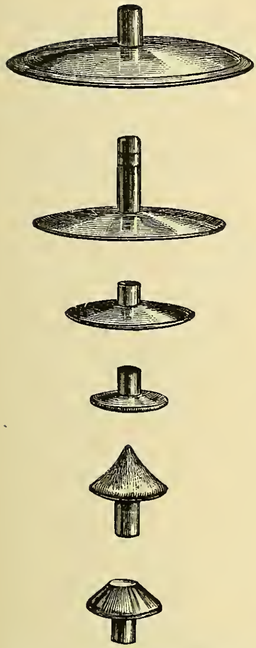

FIG. 79.—Sponge Clasps (Kidder).

FIG. 80.—Universal Handle.

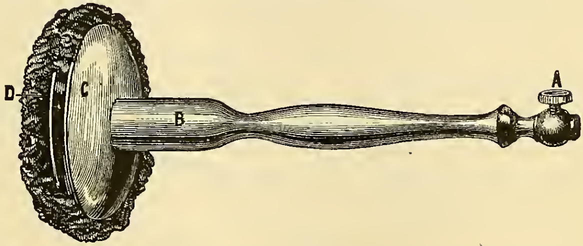

FIG. 81.—United Clasp and Handle with Sponge attached (Kidder).

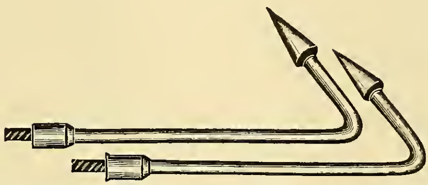

FIG. 82.—Duchenne's Electrode (G. F. Mfg. Co.).

FIG. 84.—Rockwell's Brass Ball Electrode for General Faradization (Kidder).

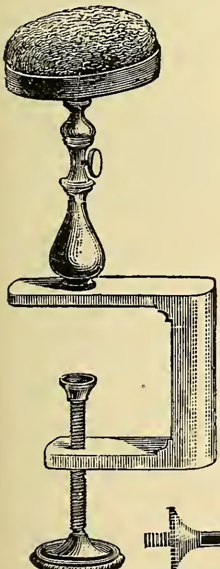

FIG. 85.—Stationary Electrode.

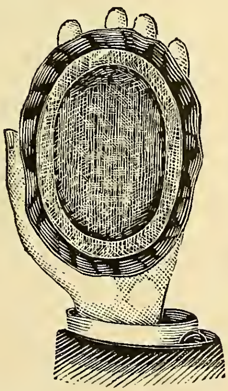

FIG. 86.—Hand Sponge Electrode (Van Houten & Ten Broeck).

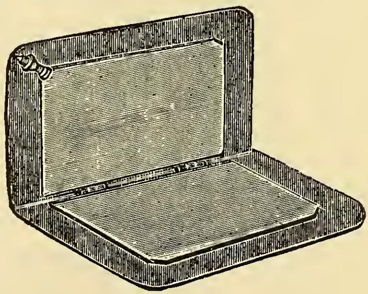

FIG. 83.—Folding Foot Plate (McIntosh).

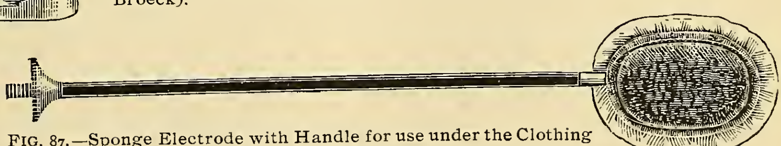

FIG. 87.—Sponge Electrode with Handle for use under the Clothing (Van Houten & Ten Broeck).

Fig. 85 can be screwed to the edge of a table. The sponge at the top can be unscrewed and moistened. In many applications to the ear, eye, head, and face this is a most convenient electrode for the hand of the patient to rest upon.

The adjustable electrodes (Figs. 88, 89), which are made of several different sizes, have long been to us indispensable. They can be fastened

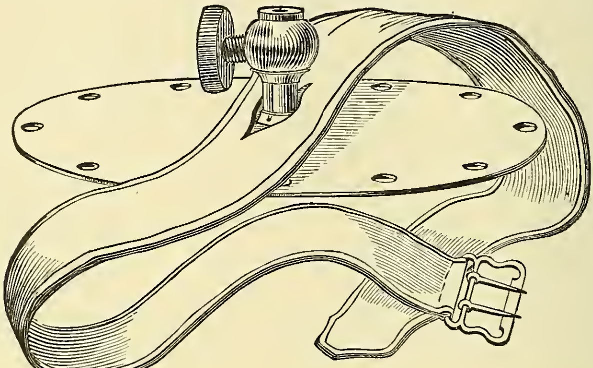

FIG. 88.—Adjustable Electrode, with Band for the Body (Kidder).

FIG. 89.—Adjustable Electrode for the Neck or Body (McIntosh).

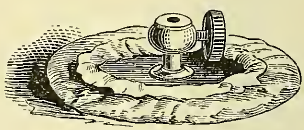

FIG. 91.—Adjustable Electrode—small size—with flannel Cover.

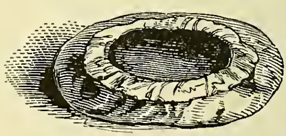

FIG. 90.—Flannel Cover for Adjustable Electrode—small size.

by means of a simple cloth band to any part of the body, and kept there as long as may be necessary.

In diseases of the skin, in rheumatism, in sprains, and in tumors, and in all cases where it is desired to keep the electrode long in one spot, they are most convenient. A second advantage which they have is, that they can be passed easily under the clothing, thus saving much undressing on the part of the patient.

These adjustable electrodes can be covered with a sponge, which can be sewed through the holes at the edge, or what is very much better, with electrode covers (Fig. 90).

We use these adjustable electrodes in central galvanization, galvanization of the cervical sympathetic, and brain and spine, and in a large variety of peripheral applications. In some applications, as in central galvanization, one electrode is adjustable, while the other, held by the patient, is of the ordinary form with a handle. We do not much use the bands that accompany them, preferring to hold the electrode in position

FIG. 92.—Spinal Electrode (Kidder).

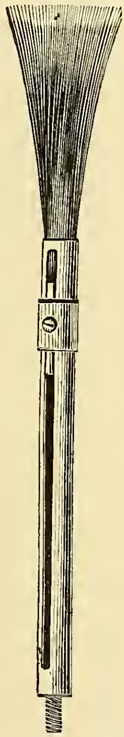

FIG. 93.—Metallic Brush (G. F. Mfg. Co.).

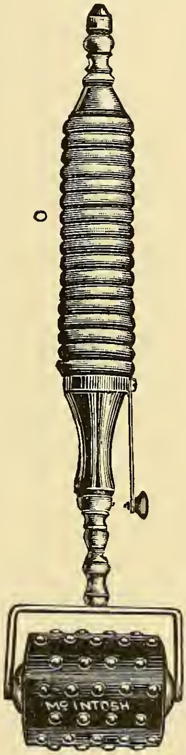

FIG. 94.—Wheel Electrode for Muscular Faradization (McIntosh).

by allowing the clothing of the patient to rest against it, or having the patient hold it, by a little pressure.

In galvanization of the sympathetic, for example, the adjustable electrode can be easily placed under the collar at the back of the neck, and kept there by the pressure of the clothing.

The flannel covers (Figs. 90 and 91) are provided with elastics in their edges so that they remain in position when put on the electrode, and are easily slipped off and on. They can be washed like towels, and the expense of making them is so slight that a large number can be kept constantly on hand. We have long been accustomed to use these covers in all mild central applications of the galvanic current.

A Current-Reverser with Flexible Electrodes.—Fig. 95 represents a current-reverser which was first constructed by Messrs. Tiemann & Co. It differs mainly in this feature from other devices to accomplish the same purposes, viz.: that the current is reversed by simple and slight pressure of the thumb, without the intervention of a slide, or any complex arrangement whatsoever.

The letter D represents the button of the spring, by pressing which, the current is interrupted or reversed. Pressing it lightly interrupts the current; pressing it firmly reverses it.

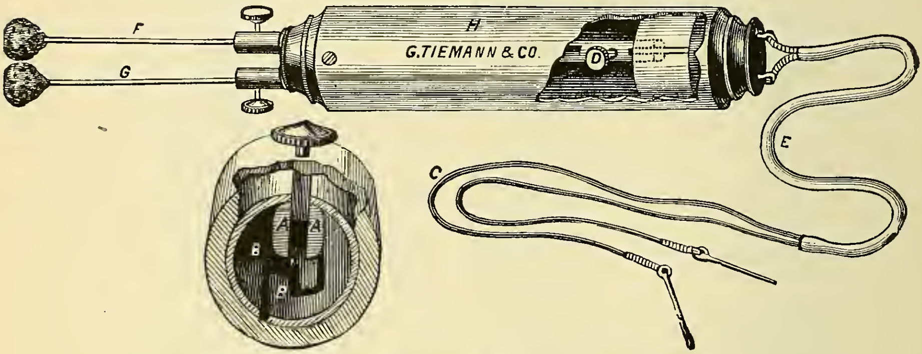

FIG. 95.—Current-Reverser, with flexible electrodes.

In the vertical section of the hard-rubber handle, A A is represented as springing up against the metallic plate on the upper and inner surface of the handle. Pressing this slightly down, metallic connection is broken and the current is interrupted; pressing it firmly down, the connection is made and reversed at B B, the metallic plate on the lower surface of the handle.

C represents the wires that connect with the battery, enclosed in a rubber tubing E.

F and G are flexible wire electrodes armed with sponges; they can be separated several inches and kept there, or put close together as represented in the cut. The advantages of this are these: 1. In many of the applications of localized electrization this neat and simple arrangement saves considerable expenditure of muscle on the part of the operator. One hand can be perfectly free while the other holds and guides the electrode. In electrizing the muscles of the hand and arm, and of the face especially, it is far more convenient than to use separate electrodes.

2. In cases of paralysis of motion and of sensation, where voltaic alternatives are sometimes indicated, this is the easiest conceivable method of reversing the current.

Unpolarizable Electrodes.—It is well known to electro-physiologists that, in consequence of the electrolytic changes that take place during the passage of a current from the electrodes to the body, a change takes place at the surface of the electrodes, by which a new electric action is set up that to a certain extent interferes with the main current and also causes pain. Electrodes thus affected are called polarized. (See Electro-Physics.)

Dr. Hitzig,* of Berlin, devised electrodes in which this secondary electric action at the surface does not take place; to these he has given the name unpolarizable electrodes. These are made unpolarizable by a solution of sulphate of zinc. The pain produced by stable galvanization is sometimes very disagreeable, and by these electrodes it is certainly diminished. They can be used several hours without exhibiting any polarization. The subject of unpolarizable electrodes had previously received the attention of Regnauld, Matteucci, and Du Bois-Reymond.

Rubber Covers for Conducting Wires.—The conducting wires connecting the electrodes with the apparatus are covered with silk; they may be still further insulated by flexible rubber. We have long been accustomed to use these rubber covers, and are much pleased with them. If the rubber is properly prepared it will not injure the silk covering beneath it. Some electro-therapeutists have rubber coverings of a different color for the two poles, thus affording a ready means of distinguishing them.

Care of Electrodes.—Electro-therapeutics is a series of details; and among the more important of these details is the care of the electrodes. The chemic action, even of the secondary coil, is sufficient to corrode any metal that is used, except platinum; and platinum electrodes are rarely, if ever, used except in electrolytic operations. The copper plates used at the feet in general faradization become more or less corroded, and require occasional cleaning in order to keep them bright. All the general and special electrodes of all kinds require occasional polishing with sand-paper, emery-paper, or whiting. It is an advantage to have the electrodes, as well as the batteries, nickelized, so as to reduce corrosion to a minimum.

The sponges that are attached to the electrodes need to be frequently washed in warm water, and those that are much used should be disinfected with chlorinated solutions. It is better, however, to make delicate and particular patients, especially ladies, supply their own sponges. But a physician who has a large general or special practice will find it very difficult, if not impossible, to keep a large assortment of electrodes, sponges, and electrode covers always separate; and hence it becomes necessary to treat many of the patients with the same electrode.

* "Ueber die Anwendung unpolarisirbarer Electroden in der Electrotherapie." Berliner klinische Wochenschrift, 1867, No. 89.

To meet this difficulty we devised the electrode covers, elsewhere described. These can be thrown off with every application and washed weekly, like towels. The expense and labor of making them is so slight that some electro-therapeutists, after using them a few times, cast them aside entirely. Absorbent cotton is also most convenient and useful as a covering for electrodes, as well as inexpensive.

CHAPTER IX.

LOCALIZED ELECTRIZATION.

The object of localized electrization is to confine the direct action of the current, as far as possible, to some particular part of the body.

This is accomplished by placing electrodes so that the current, in passing from one to the other, shall chiefly traverse only that particular part that is to be affected.

Both currents may be localized in this way, hence the division of localized electrization into localized faradization and localized galvanization.

The scientific use either of localized galvanization or faradization requires as accurate as possible preliminary diagnosis of the disease.

In cases of doubt it is necessary to electrize in succession all the suspected localities until the results of treatment show conclusively that we have hit upon the seat of the disease. Accordingly, in obstinate or doubtful cases the head, the cervical sympathetic, and the spine, and in some instances the uterus or organs of the abdomen, are to be successively electrized.

In the very numerous cases of doubt also, when the locality of the disease cannot be ascertained, as well as in conditions of irritation where electrization of the seat of the disease will not be borne, peripheral applications alone are frequently of decided service. For peripheral applications both the galvanic and faradic currents are used; for central applications, chiefly the galvanic. In some diseases, as, for example, locomotor ataxia, in certain stages it is better to treat the prominent symptoms, as, for example, the anæsthesia, than the seat of the disease in the spine.

Instruments for Localized Electrization.—In localized electrization the same galvanic and faradic apparatus are used as in general electrization. For localized electrization in all its modifications there are needed a variety of electrodes of different shapes and sizes, to reach the various localities and accomplish the different indications.

Of the electrodes there are three general forms: the electric hand; the metallic brush; solid metals and metals covered with sponge, flannel, linen, or chamois, thoroughly moistened.

Dry or Cutaneous Faradization.—To accomplish dry faradization the portion of the skin over which the application is to be made should be wiped thoroughly dry, or, what is better still, sprinkled with some absorbing powder, as the common nursery powder; and the application may be made with the dry hand of the operator, or with metallic electrodes.

In dry faradization with the hand there is heard a peculiar crackling sound, which is caused by the sparks that take place as the current passes from different points of the hand to the skin.

When the dry hand is used, the operator passes the current through his own person, one of the electrodes applied to some near point by an assistant, or held in the hand by the patient himself. Solid metallic electrodes of various shapes may be used for dry electrization.

Dry electrization by the metallic brush with a strong current, faradic or galvanic, is a very painful method of application, and is to be resorted to only in those cases where there is profound cutaneous anæsthesia or analgesia. In all cases where there is great sensitiveness the hand is to be preferred to any form of artificial electrodes.

Electric Moxa.—The so-called electric moxa is produced by using a metallic brush, plate, or point, and one moistened electrode. The dry electrode is rapidly touched to the surface where the moxa is to be made, while the other is kept firmly applied to some near and indifferent point. The surface of the skin may previously be rubbed very dry, or sprinkled with some absorbing powder.

The operation requires a current of some strength, and is exceedingly painful. It is chiefly employed as a counter-irritant in neuralgia associated with anæsthesia, in which affection it is frequently successful. The electric moxa may also be produced by means of two metallic brushes, one of which is pressed on the skin.

Electrization with Moistened Electrodes.—When it is desired to affect the tissues lying beneath the epidermis, it is better to use electrodes covered with sponge, chamois, or flannel, thoroughly moistened with salt water or ordinary water.*

The size and shape of the electrode employed must be modified according to the situation and sensitiveness of the part where the current is to be localized, and also by the sensitiveness of the patient. As a rule, small, finely-pointed electrodes are required for localized faradization of single muscles, larger electrodes for large muscles or groups of muscles, and those with the largest surface for galvanization of the sympathetic, brain, and spine.

When the current is localized by means of moistened electrodes, it diffuses itself through the body between the electrodes in various directions. The extent of this diffusion will be variously modified by the situation of the electrodes and the structure and relation of the parts that lie

* In faradization we never or but rarely use salt in the water; in galvanization it is sometimes a great advantage, because it overcomes in a marked degree the resistance of the skin.

between them (see Electro-Physiology). It is manifest also that the density of the current, other conditions being the same, will be greatest near the electrode and least at the farthest point between them. The strength of the current being the same, small electrodes are more painful than those with a broad surface, and metallic more than the wet sponge or flannel. An electrode covered with sculptor's clay is the least painful form of electrode.

Direct and Indirect Electrization.—Two general methods of localized electrization are recognized—the direct and the indirect. In direct electrization the application is made over the muscle to be excited. In indirect electrization the application is made to the nerve which supplies the muscles. In the former method, large electrodes are preferred; in the latter, usually those which are small and pointed. The faradic current is best indicated for direct electrization, and the galvanic for indirect.

The points where the motor nerves enter the muscles are called "motor points." They have been carefully demonstrated and located by Ziemssen and ourselves.

Definition of Terms.—In *stable* applications both electrodes are kept in a fixed position.

In *labile* applications one of the electrodes is moved or glided over the surface; sometimes both of the electrodes are moved simultaneously.

A current is called *continuous* when it is allowed to flow in one direction without interruption. Only the galvanic current can be continuous, since the faradic is always in a condition of interruption.

A current is called *interrupted* when it is broken by removing one of the electrodes, or by some form of current-breaker in the electrode, or by any method of breaking the circuit. The faradic current is always interrupted by its rheotome, but it may be still further interrupted by removing one of the electrodes.

A current is called *uniform* when it remains of the same strength during the applications of the electrodes.

A current is called by us *increasing*, when its strength is gradually augmented during the applications. This method possesses a great advantage in treating conditions of irritation and inflammation. It may be used with both galvanization and faradization. A much more powerful current can be borne when its strength is gradually increased than when it is suddenly let on in full force with the first closure of the circuit, as is very often done. A current which when suddenly closed may cause unbearable pain, and, when applied near the nerve-centres, may induce dizziness and faintness, may oftentimes be borne without discomfort and with positive advantage if it is gradually increased from a very mild current. With the faradic current a mild anæsthesia is produced.

Increasing currents are indicated in applications to the brain, sympathetic, spinal cord, the eye and ear, urethra, inflamed joints, and to all conditions of great irritation in any part of the body.

All faradic apparatus are constructed so that the current can be gradually increased. To gradually increase the galvanic current, a rheostat of some kind is needed. The galvanic current can also be increased by an arrangement that gradually adds to the number of elements without interrupting the current, or when a sponge electrode is used, by slowly increasing the pressure.

The term *voltaic alternatives* is applied to those applications in which the direction of the current is reversed continually, while the electrodes are kept firm. The current-reverser is a very convenient instrument for producing voltaic alternatives.

For electrization of muscles, labile or stable interrupted currents are preferred. For electrization of the head, spinal cord, sympathetic, and nerve-tracts and plexuses, stable continuous currents are indicated, and these again may be either uniform or increasing. Labile or stable interrupted currents are best adapted to produce muscular contractions, and cause most potent physical and mechanical effects, while stable continuous currents, whether uniform or increasing, produce the strongest electrolytic or catalytic action.

In cases where the electro-muscular contractility is not greatly diminished, it is an advantage to use electrodes with a broad surface, since thereby several motor points may be influenced simultaneously, together with a considerable extent of muscular tissue, and because they are less painful than small electrodes. In such cases the faradic current is preferable.

When the electro-muscular contractility is very greatly diminished, as so frequently happens in paralysis, contractions are best produced by small, finely-pointed electrodes, applied at the motor points of the individual muscles; yet even here electrodes of moderate size are usually preferable. Such cases often require the galvanic current.

Details of Applications of Localized Electrization.

Galvanization of the Central Nervous System.—It is necessary to bear in mind at the outset that to produce effects on the brain, spinal cord, and sympathetic, the galvanic current is preferable to the faradic, although the faradic current certainly affects the nerve-centres reflexly, if in no other way.

Galvanization of the Head.—The head may be electrized in a variety of ways, according to the supposed seat of the disease. One pole may be placed on the forehead and the other on the occiput; or both poles may be placed over the ears, or on the mastoid processes. Another method which we frequently adopt is to place the positive pole on the summit, over the supposed organ of firmness, and the other at the occiput, or under the chin.

To affect the base of the brain, the electrodes may be placed on or behind the mastoid processes. To confine the action to one side of the brain, one electrode may be placed on the forehead, over the eye, and the other on the mastoid process of the same side. The patient may hold one of the poles in the hand. Still another method less used is to place an electrode on each temple.

Less dizziness is caused if the current is opened and closed with the positive than with the negative pole. It is well, therefore, to first apply the negative pole.

Less dizziness is caused when the current flows through one side of the head, or from the forehead to the occiput, than when it is sent from one side to the other, through the mastoid processes.

The use of some kind of a rheostat, so as to avoid interrupting the current or giving sudden "shocks" on closing and opening, is almost indispensable in electrizing the brain and neck. With regard to the direction of the current, it is usually better to place the negative pole nearest the neck, and the positive pole nearest the forehead. But this rule is liable to many exceptions, and each case must be studied by itself.

Interruption of the current produces flashes of light through irritation of retina, and dizziness, which with many is exceedingly disagreeable and may prove harmful. If the application is too long continued, headache and insomnia and general malaise may result. Patients whom a short application through the head benefits are sometimes injured when the *séance* is protracted. Galvanization of the head should be made with broad electrodes, with a stable current, which may be either uniform or increasing, and should not exceed from one-half a minute or three-quarters of a minute, to five or ten minutes, and with a current strength varying from one to fifteen or twenty milliamperes.

In a general way, it may be said that a strength of current is indicated that can be borne without special pain or discomfort to the patient.

Galvanization of the Cervical Sympathetic.—The portion of the sympathetic to which galvanization is chiefly directed for therapeutic purposes is the cervical, although the cephalic, thoracic, and abdominal ganglia are unquestionably affected by it, though not with so specific, demonstrable, and immediate results.

There are a number of methods by which the superior, middle, and inferior cervical ganglia may be demonstrably affected by the galvanic current.

1. One electrode with an oblong extremity is placed just below the auriculo-maxillary fossa, while the other with a larger surface is applied over, or by the side of the sixth and seventh cervical vertebræ (see Fig. 96).

The second electrode may also be applied at any point along the spine, from the occiput to the coccyx. It is by this method that diplegic contractions are usually produced with most success.

2. The first electrode being placed as before, in the auriculo-maxillary fossa, the other, with a surface of moderate diameter, is applied just above the manubrium sterni, by the side of the sterno-cleido-mastoid muscle (see Fig. 97).

The second electrode may also be applied higher up in the neck, opposite the middle cervical ganglion.

The above are the two methods which have been most frequently employed. Other methods are the following:

3. The first electrode being placed as before, the other may be applied

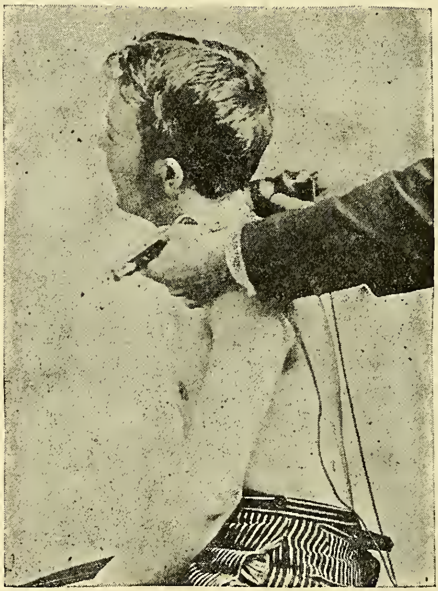

FIG. 96.—Galvanization of the Cervical Sympathetic.

on the shoulder, elbow, or in the hand of the opposite side, or in the axilla.

4. Both sides may be galvanized simultaneously, by placing an electrode over the mastoid processes.

5. One electrode is placed just above the manubrium sterni, and the other at any point down the spine.

6. One electrode is placed over the sixth and seventh cervical vertebræ, and the other over the brachial plexus, at the pit of the stomach, just above the manubrium sterni, in either hand, or at the feet.

In all these methods either direction of the current may be used, according to the effects desired.

Applications to the sympathetic should be made from one to ten minutes, and with a current strength of from five to fifty milliamperes, according to the position and size of the electrodes and individual susceptibility. Several methods may be tried at a single sitting in cases where the applications are well borne.

Bearing in mind that in all such attempts to galvanize the cervical sympathetic, the pneumogastric and spine must be more or less influenced, the general indications for the use of this method of treatment to which experience would seem to point are these:

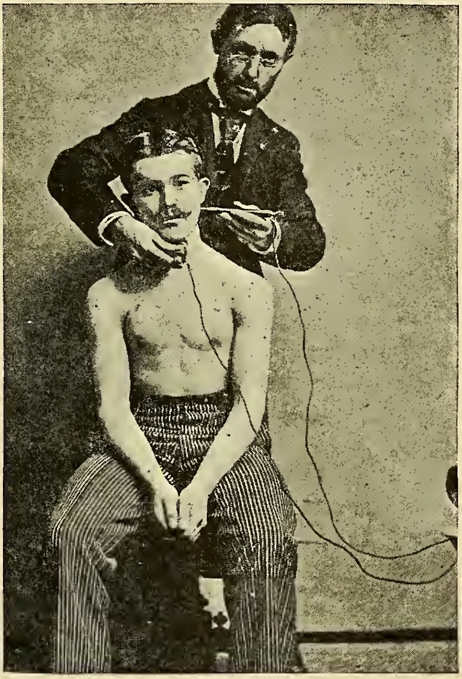

FIG. 97.—Galvanization of the Cervical Sympathetic, including the Pneumogastric.

1. Cerebral anæmia and hyperæmia. These conditions are associated with and are a part of a large variety of diseases. Insomnia, hemiplegia, tic douloureux, many diseases of the eye and ear, as neuro-retinitis, nervous deafness, and tinnitus aurium, are all more or less associated with cerebral anæmia, hyperæmia, and all have been treated by galvanization of the cervical sympathetic, with more or less success.

2. Disorders of the vaso-motor nerve. Under this head may be included some cases of deficient circulation, cutaneous hyperæsthesia, certain diseases of the skin, and exopthalmic goitre.

3. Functional diseases of the digestive and genital apparatus. Gal-

vanization of the sympathetic in these conditions seems to work, partly at least, by reflex action, and partly, also, by the influence which the spinal cord and pneumogastric receive during the applications.

It is scarcely necessary to remark that the exclusive use of galvanization of the cervical sympathetic is indicated only in exceptional cases. It is to be employed in connection or alternation with general faradization and galvanization of the brain, spinal cord, and periphery. A noteworthy advantage of this method of treatment in those cases for which it is of service is the comparatively short time required for its employment.

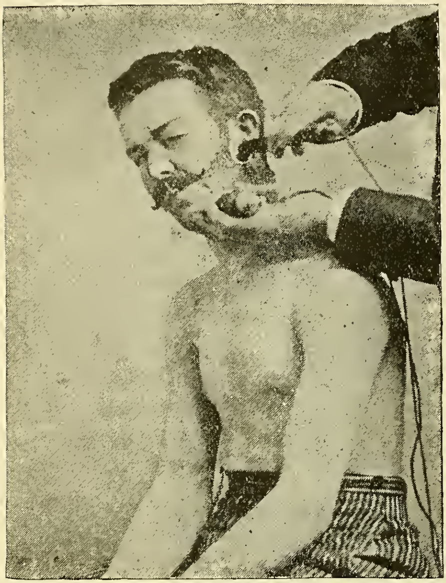

FIG. 98.—Faradization of the Facial Nerve and Muscles. Eyelid firmly Closed and Mouth drawn to one side.

The objection that galvanization of the cervical sympathetic is a dangerous procedure will be considered in the chapter on central galvanization.

Galvanization of the Spine.—The spine may be electrized by placing one electrode at the occiput, and the other at the coccyx. One of the electrodes may be kept *in situ*, while the other is slowly passed up and down the entire length of the cord. Either pole may be passed up and down in this way according to the effect desired.

The current may also be localized in any part of the spine that may be required, by giving the electrodes the proper position. With electrodes of soft sponge or, better still, of sculptor's clay, a current strength of fifty milliamperes can in many cases be given without special pain. The applications should be sensitively felt like a gentle mustard plaster, but should not be excessively painful, like a blister.

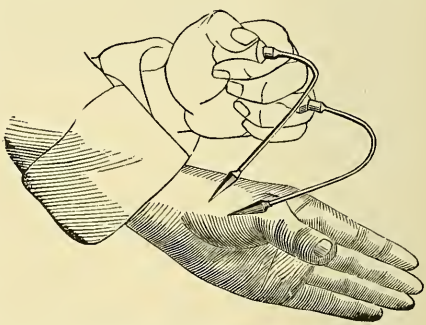

FIG. 99.—Muscular Faradization with Metallic Electrodes (Duchenne).

Electrization of Plexuses, Nerves, and Muscles.—Plexuses, nerves, and muscles are treated by both currents.

One electrode may be applied to a plexus and the other to one of its branches, or to a muscle or group of muscles. Both electrodes may be

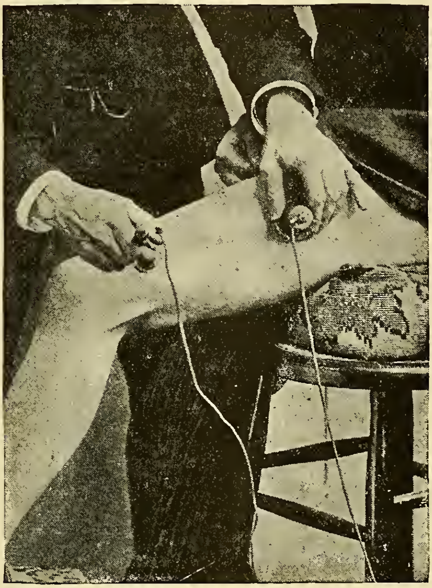

FIG. 100.—Faradization of the Muscles of the Thigh, contraction of the Quadriceps.

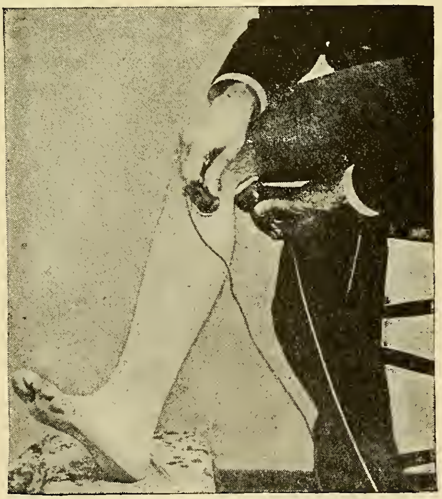

FIG. 101.—Faradization of Popliteal Nerve and Peroneal Muscles. Foot brought upward and outward.

applied to the nerve, or one to the nerve and the other to a muscle; or both may be applied to a muscle or group of muscles. All these applications may be made either with or without regard to the direction of the current, and different methods may be tried at the same *séance*.

In all the positions described in the above cuts, contractions should be produced with mild faradic currents, when the electrodes are in the position represented. If very strong currents are necessary or no contractions are possible, the muscles are in a condition of disease.

Peripheral applications are indicated where the disease is purely of a peripheral character; the partly central applications are indicated where the disease is of a central origin.

Labile interrupted applications are indicated where it is desired to produce mechanical effects or muscular contractions, as in anæsthesia and paralysis.

Stable continuous application are indicated where it is desired to produce electrotonic, chemic, or catalytic effects, as in neuralgia.

Benedikt* makes the following somewhat over-refined subdivisions of the methods of galvanization of the centre and periphery:

Spinal-cord current: both poles are placed on the spine, either near together, or at some distance from each other.

Spinal-cord-root current: one pole is placed on the spine, and the other is passed up and down by the sides of the vertebræ.

Spinal-cord-plexus current: one pole is placed on the spine, and the other on a plexus of nerves.

Spinal-cord-nerve current: one pole is placed on the spine, and the other on a nerve.

Spinal-cord-muscle current: one pole is placed on the spine and the other on a muscle.

Plexus-nerve current: one pole is placed on a plexus of nerves and the other on a nerve.

Nerve-muscle current: one pole is placed on a nerve and the other on a muscle.

These currents may be either stable or labile, continuous or interrupted, uniform or increasing.

The method of electrizing the eye, ear, nose, larynx, œsophagus, heart, lungs, stomach, liver, kidneys, spleen, intestines, rectum, bladder, male and female organs of generation, will be described in the chapters devoted to diseases of these organs.

The method of electrizing individual nerves and muscles has been described and illustrated in the chapter on electro-therapeutic anatomy.

Effect of Current Modified by the Length of Application.—The sensations and the effects of electric applications are considerably modified by the length of time that the electrodes are kept in position. When the faradic current is first applied to the skin, it causes a stinging, pricking

* Op. cit., p. 56.

sensation, perceptibly strongest at the negative pole; if the electrodes are kept in position the sensation may gradually diminish, and the parts will

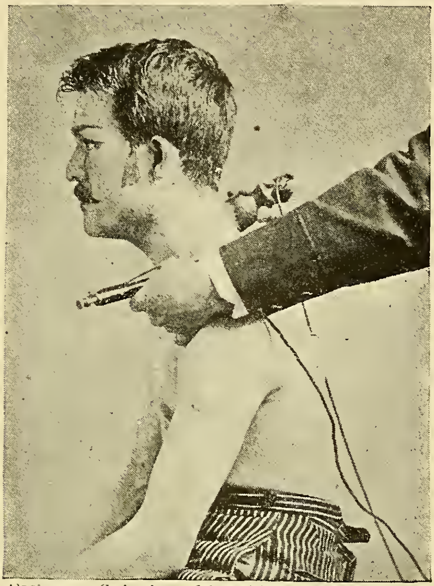

FIG. 102.—Spinal-cord-brachial plexus current.

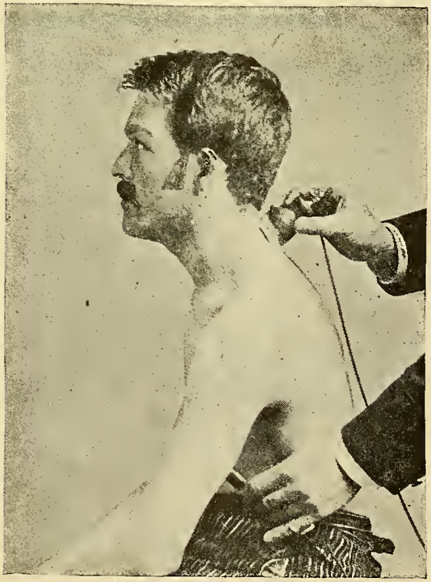

FIG. 103.—Spinal-cord-median nerve current.

become very slightly benumbed, and if now the strength of the current be gradually increased, little or no additional pain is caused. If the current is at first very strong, it cannot be borne long enough to produce this benumbing effect.

When the galvanic current is first applied to the skin it causes no sensation or scarcely any, unless it be very strong or is directed over or near a motor nerve; if the electrodes are kept in position for a few seconds, a slight burning sensation is felt at both poles, but strongest at the negative. This burning sensation increases quite rapidly until the sensation it causes is like that of a strong mustard plaster, or hot iron, and becomes unendurable. The benumbing effect of the faradic current is not experienced. This increase of the pain under the galvanic current is due to two causes—the moistening of the skin through the moisture of the electrode, so that it becomes a better conductor of electricity, and the special chemic action of the poles. This increased conductivity of the skin is the partial if not complete explanation of the fact that the muscles contract under a feebler current after the electrodes have been some time in one place. It is not impossible, however, that the nerves or muscles may be so stimulated by the current as to contract more readily than before stimulation.

The reverse proposition, that strong currents used for a long time enfeeble the nerves and muscles so that they respond less readily to the current, is certainly true, and is easy of demonstration, especially in cases of facial paralysis. For this reason, prolonged applications frequently do more harm than good.

Effects of Localized Electrization.—Localized electrization has to a limited extent the same direct effect on the part to which the application is made that general electrization has on the whole body. It acts as a locally stimulating tonic.

Improvement in Local Nutrition the Leading Effect of Localized Electrization.—The leading and general effect of localized electrization, and one which is a complex result of the various special effects, is improvement in local nutrition.

Localized electrization of an atrophied or poorly nourished muscle causes that muscle to improve in size and strength; localized electrization of an atrophied or poorly nourished organ, as the uterus, causes it to increase in size and improve in functional activity.

Localized electrization of any part of the cerebro-spinal system improves the nutrition of that part, and as a result the whole body, over which the cerebro-spinal system presides, may improve in nutrition. Thus localized may indirectly have some of the same effects as general electrization. Similarly, also, as we descend from the centre toward the periphery electrization of any nerve branch or plexus improves the nutrition, not only of the nerve acted on, but also of its various branches and of the muscles and organs that it supplies.

When the nutrition of an atrophied part is improved it grows larger;

when the nutrition of a hypertrophied part is improved it grows smaller. The same treatment that makes a flabby muscle increase in size causes a goitre to diminish in size. These opposite effects of the local use of electricity, though apparently inconsistent, are yet quite consistent (see Electro-Physiology, and Electro-Surgery, chapter on Tumors).

The special effects of localized, unlike those of general electrization, cannot be broadly stated or classified, for the obvious reason that they must so largely depend on the locality to which the application is made.

Although applications to the central nervous system are sometimes followed by mild and limited degrees of the primary, secondary, and permanent effects that result from general faradization or central galvanization, yet the cases where the full order of these effects is so marked and decided as to be observed are comparatively unfrequent.

Applications to the brain and sympathetic system may be followed primarily by relief of pain, slight exhilaration, a feeling of warmth or somnolence; secondarily by fatigue, headache, or soreness of the muscles, or exacerbation of the morbid symptoms; and permanently by improvement in sleep, strength, and capacity for labor.

But this order of effects from localized electrization is exceptional, even from applications made to the head. More frequently the permanent effects are experienced without the primary, or perhaps both the permanent and secondary, and sometimes only the latter.

Yet none of these constitutional effects, in whatever order they may occur, are experienced to the extent that is derived from general faradization.

The agreeable symptoms which are most frequently observed after localized applications to the nerve-centres are disposition to sleep, relief of headache or other pain, and occasionally slight exhilaration.

Sometimes the beneficial results of electrization of paralyzed muscles follow immediately after the application. The patient is conscious of an ability to use the muscles treated with greater ease and freedom. This improvement may be merely temporary, or, as is more frequently the case, partial relapses occur, leaving a certain amount of permanent benefit. Immediate relief of neuralgic pain, and of the reverse condition, anæsthesia, may follow localized as well as general electrization. The temporary relief of the neuralgia may be complete, while that of anæsthesia is usually only partial and limited. In both conditions the evil symptoms may recur, or a certain amount of permanent benefit may remain.

Among the disagreeable symptoms are dizziness, heaviness, oppression, headache, soreness in the muscles, exhaustion, and indefinable nervousness.

These disagreeable symptoms are most likely to result from applications that have been either too severe or too protracted for the condition of the patient; and yet they should by no means excite alarm, since they often accompany the most successful results. These unpleasant symptoms are more likely to follow the use of the galvanic current than the faradic, especially when the applications are protracted. The opinion that has been expressed by certain writers, that the head is more likely to be unpleasantly affected by the faradic than the galvanic current, is not sustained by experience. The phenomena of dizziness, heaviness, etc., frequently experienced after even a very short application to the head, are but rarely observed when the faradic current is employed.

Applications of localized electrization to individual muscles or groups of muscles rarely give rise to any constitutional symptoms whatever, unless the electrodes are placed on or near the head.

The special effects of localized electrization of special organs, as the eye, ear, larynx, stomach, liver, intestines, uterus, ovaries, bladder, etc., will be described in the chapters devoted to the treatment of the diseases of these organs.

Absolute Localization of Electricity Impossible.—It should be considered that exclusive and absolute localization of the effects of electrization is impossible. The effects of both currents extend, either directly or by reflex action, to parts beyond the circuit. This is demonstrated, not only by physiologic experiments, but by the observed facts of clinical experience. Thus it is observed, in some irritable conditions, that galvanization of the spine, and even of the extremities, causes a metallic taste; that galvanization even of the hands or feet sometimes hastens or increases the menstrual discharge, relieves headache, and produces sleep. The same effects to a less degree are sometimes observed from faradization.

Some of the illustrations of this fact are quite striking. Thus in the case of a woman, the wife of a physician, whom we were treating by faradization of the shoulder for rheumatism, the menstrual flow was so much increased and prolonged that it was necessary to abandon the treatment, although only very mild currents and short applications were used.

In the case of a lady whom we were treating for sciatica, by localized galvanization of the painful portion of the nerve, the pain was decidedly relieved, but the effect was to bring on a recurrence of the menses after they were suspended, so that the patient was nearly all the time menstruating.

These illustrations are extreme and comparatively rare, but they serve to show clearly enough that the effects of electrization cannot well be localized to the points between the electrodes, and that other and distant parts must, of necessity, be more or less affected.

The term localized electrization, introduced by Duchenne, is therefore, strictly speaking, a misnomer, since we are taught by physics that the vibrations of the electric force must diffuse themselves in various directions, and at a considerable distance from the electrodes, and we are taught by clinical experience that the effects of electrization, however near together the electrodes may be placed, are not entirely confined to the points between or near the electrodes, but may be felt, and in some instances far more demonstrably, in distant parts and organs.

To the use of the term localized electrization there is no objection, provided it be used understandingly, and with the idea that it is merely a term of convenience. The term local electrization is often used synonymously with localized electrization, and for the reasons here suggested is preferable to it. Localized electrization has the advantage of being first in the field, and has become, to a certain extent, consecrated by usage.

CHAPTER X.

GENERAL FARADIZATION.

THE object proposed in general faradization is to bring every portion of the body under the influence of the faradic current, so far as is possible, by external applications. This is best accomplished by placing one pole (usually the negative) at the feet or the coccyx, while the other is applied over the surface of the body.

The faradic is the current which is almost exclusively employed in general electrization, and for that reason the directions and explanations given in this section, with the exceptions that will be noted, apply mainly and specially to general faradization. Since the discovery of central galvanization, to be hereafter described, we have discarded the term general electrization, and substituted general faradization, for the reason that the galvanic current is preferably used in the form of central galvanization.

In the majority of cases it is more convenient and satisfactory to have a sheet of copper at the feet. This position is indeed the rule in general faradization. The broad, callous soles of the feet are but slightly sensitive, and will bear a stronger current than any other portion of the surface of the body. But the passage of electricity through the ankles causes vigorous contractions of the flexors and extensors, which, when the current is very strong, may be somewhat painful. Accordingly, when the patient is peculiarly nervous and sensitive, or when a current of unusual strength is to be employed, and in all cases where a stronger application is desired than can be borne through the ankles, or when it is desired to save time or inconvenience, it is advisable to have the patient sit on the plate, or a sponge electrode with a broad surface may be applied to the coccyx.

In general faradization, as in localized, the currents may be stable (stationary) or labile (moving), uniform or increasing.

Increasing currents are adapted for certain important centres, as the head, spine, cervical sympathetic, and cilio-spinal and epigastric regions. The advantage of this method of application is that it allows the use of a stronger current than will otherwise be borne; the strength of the current may be so very gradually increased that the increase within certain limits may be almost imperceptible to the patient. This arises partly from the fact that the current has a slight benumbing or anæsthetic effect (see

Electro-Physiology, and partly from the fact that by a gradual increase of the strength of the current the patient is spared the shock that is experienced when a strong current is suddenly directed through sensitive portions of the body.

Labile and interrupted currents are adapted for the muscles, especially of the extremities.

General faradization is very far from being so easy a process as it might appear from this brief description. Its successful employment requires, on the part of the operator, some mechanical dexterity, entire familiarity with the instruments required, a complete knowledge of electro-therapeutic anatomy; a personal acquaintance with the sensations and behavior of all portions of the body under the different electric currents; close and patient study of the diseases and morbid conditions in which it is indicated, and of their response to faradization. There are those who by long practice are enabled, when necessary, to readily manipulate any portion of the body with either hand, while there is passing through them a current so powerful as to keep many of the principal muscles of the arms in a state of contraction. This qualification, however, though convenient, is not indispensable.

On the side of the patient, success in the use of general faradization requires something of the same patience and perseverance that are conceded to be necessary for success in the use of any other form of electric treatment.

Nothing is more difficult than to fully and accurately describe in words an operation that in its very nature demands actual sight and experience. The true method of learning the art of general faradization is by repeated observations of its application to the living subject, by personal experience of its sensations and results at the hands of practised adepts, and by long and various experimenting on diverse temperament, and in opposite states of disease. We shall endeavor, however, to present the best possible substitute for a course of private lessons or extended clinical observation in this department, by answering in detail the practical questions that naturally present themselves to one who approaches the subject *ab initio*, and who has no opportunity for personal interviews with those to whom the various steps of the operation have become already familiar.

Position of the Patient.—The patient should be seated on an ordinary stool, with his face toward the instrument, and his feet on the sheet of copper to which the negative pole is attached. Any chair that has a back or arms will somewhat interfere with the manipulations of the operator.

Those patients who, through paralysis or debility, are unable to sit up at all, can receive the treatment while lying in bed or on a lounge. In such cases the sheet of copper may be placed upright against a pillow, and the feet of the patient pressed against it, or an electrode may be placed at the coccyx. Assistance will then be required to turn the patient when the application is made to the back and spine, but in such cases partial applications are frequently all that are required.

Infants and very feeble or very timid children should be held in the lap of the mother or nurse, while an assistant holds the sponge to the coccyx.

While the application is being made to the lower limbs it is well for the patient to stand, in order that the operator may have access to the gluteal regions and the posterior and anterior surface of the thigh.

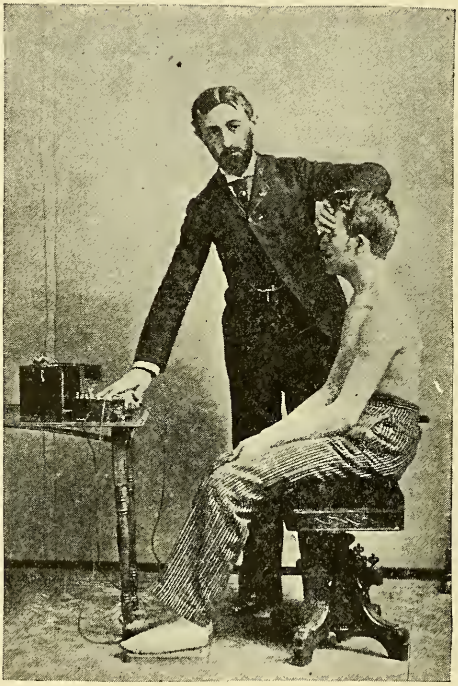

FIG. 104.—General Faradization. Application to the head by the hand of the operator. In this, as in all of the cuts of general faradization, for convenience of illustration the patient is represented without any covering. In the majority of cases they are protected by a shawl or wrapper, and frequently the underclothing is not removed.

Position of the Operator.—While making applications to the trunk, the operator may either stand or sit by the side of the patient, conveniently near to the table, on which are placed the apparatus, electrodes, sponges, bowl of water, and other appliances that may be called for during the application.

While operating on patients taller than himself the operator will find it easier to stand, especially while treating the head and upper portion of the trunk. While treating short patients the operator will find it less fatiguing to sit in a chair. Most operators will find it very convenient to change their position from a sitting to a standing posture, or from one side of the patient to the other, while making the applications to the various parts of the trunk.

Minor Apparatus.—Electrodes, sponges, and copper plate.

The best electrode for the pole that is applied over the patient is a brass ball of about one inch in diameter.

Around this brass ball should be loosely folded a soft wet sponge, of about six inches in diameter. This is found, by experience, to be by far

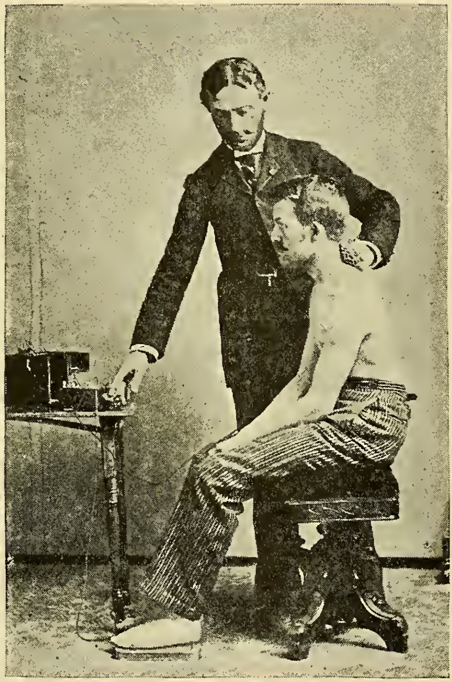

FIG. 105.—General Faradization. Application to the spine. The hand of the operator is on the metallic tube, in a position to increase or diminish the current as may be needed.

the most convenient form of artificial electrode that can be devised. Next to the moistened hand of the operator it is the most agreeable to the patient of any shape or quality of electrode. The sponge can be pressed or folded over the brass ball so as to make a comparatively small electrode, or its entire surface may be applied.

When the operator allows the current to pass through his own person, and uses his hand as an electrode, holding the sponge and ball in his other hand, he can modify the application to any degree of strength or mildness that he may desire, by simply increasing or diminishing the pressure of his hand or fingers on the sponge. Used in this way the sponge holding the water acts like a hydro-rheostat. When it is necessary that the application should be particularly gentle and cautious, it is well to rest the ball and sponge on the table and to begin the treatment by first pressing one hand firmly over the part desired to be affected, and with the other lightly and delicately touching the sponge, at first with one finger, then with two, three, and four successively, and finally with the whole hand, thus giving a very gradually increasing current. An electrode where the sponge is covered at the back with rubber, is very convenient for general faradization.

A piece of copper plate is recommended for the negative electrode, because it is found by experience to be, on the whole, more convenient than any other arrangement that has yet been suggested. The bowls of warm water, large sponges, etc., that have been suggested, are not only much less cleanly and convenient than the copper plate, but are also much poorer conductors. Metallic slippers are more troublesome than the broad plate, though their appearance, perhaps, is more ornamental. It needs more care to put on the slippers, and if the patient loses his self-control during any stage of the application, and throws up his feet, it is something of a task to find the slippers again and accurately adjust them.

In the use of the copper plate these details must not be forgotten: First, to keep it well warmed, in cold weather; secondly, to keep it slightly moistened with warm water, in order to improve the connection.

If only one foot is applied to the copper plate, the pain in the ankle, during certain stages of strong applications, will be unendurable. In mild applications it is sufficient to have one foot on the plate. It is necessary ever to bear in mind the rule, that the pain of electric applications, other conditions being equal, is in inverse proportion to the surface of the electrode. The larger the surface of the electrode—whether positive or negative—the less the pain. In this fact consists the advantage of using large sponges.

In general faradization the pain at the negative pole is chiefly felt at the ankles, and somewhat at the toes, but not on the bottom of the feet. The feeling of constriction in the ankles is caused by the rapid and violent contractions of the muscles. If only one foot is applied to the plate the entire force of the current must, of course, be borne by that foot, and furthermore, the other limb will receive no direct benefit from the treatment.

The trouble of removing the shoes and stockings may be obviated by placing a large sponge connected with the negative pole at the coccyx, or on the thighs.

Facility, skill, and readiness in use of the various methods of modifying the strength and quality of the current is one very important secret of success in the use of general faradization. A skilful operator will cause less discomfort with a strong current than one who is awkward will cause with a very weak current.

Details of the Applications to the Different Parts of the Body.—As the various parts and organs of the body differ very widely in their susceptibility to faradization, and in the effects which they receive from it, it becomes necessary to explain the *modus operandi* of the applications with considerable fulness of detail.

Applications to the Head.—The head, especially the forehead, is, by far, more sensitive to the electric currents than any other portion of the surface of the body. The two reasons for this are sufficiently obvious. The surfaces of bones are always sensitive to the faradic current, as to any other mechanical influence; and the cranium is no exception to this law. Then, again, the fifth pair is an exceedingly sensitive nerve in all its ramifications, and especially over the forehead.

There are many cases that do not bear even mild applications to the front and top of the head, and who seem to be injured rather than benefited by it. With others the effects are highly agreeable.

In treating the forehead the operator should first press his moistened hand firmly over the head, and then making the connection with his other hand on the sponge and brass ball of the positive pole, should allow the current to pass steadily, without interruption, for one or two minutes. The use of the hand as an electrode is particularly desirable in making applications to the forehead.

Moistening the Hair.—The dry hair is a non-conductor, and therefore it is always necessary to wet it freely before electrizing any portion of the head that is covered by it. It is not usually desirable to compel lady patients to pull down their hair, or to thoroughly moisten it. A very important centre for affecting the brain is the crown of the head, between the ears, over the so-called organ of firmness—the cranial centre. If the hair at this point be sufficiently moistened to admit the passage of a mild current with any convenient form of electrode, a peculiar and slightly painful sensation is experienced.

In some exceptional cases of disease the head will bear currents of considerable strength. The back of the head over the cerebellum will usually bear quite strong applications. The current is felt through the ramifications of the occipital nerves, giving rise oftentimes to sensations not only painless, but absolutely agreeable.

Applications to the Neck and Throat.—The back part of the head and upper portion of the spine will usually bear powerful applications. It is an interesting and important fact that very marked effects may be produced by general faradization, even when the applications are made only to the back and sides of the neck.

The reason for this will be clear when we come to study the electro-therapeutic anatomy of the parts. From the upper portion of the spine and base of the brain proceed the most important and most sensitive nerves of the body—the pneumogastric, and the brachial plexus, and the phrenic nerves.

Furthermore, the sympathetic or ganglionic system runs close by the spine, near to the carotid artery, and may be reached and affected electrically by pressing firmly with the fingers, by the anterior border of the sterno-cleido-mastoid muscle, at those points where the pressure of the carotid is most readily felt.

If the sponge be pressed firmly on the cilio-spinal centre, over the

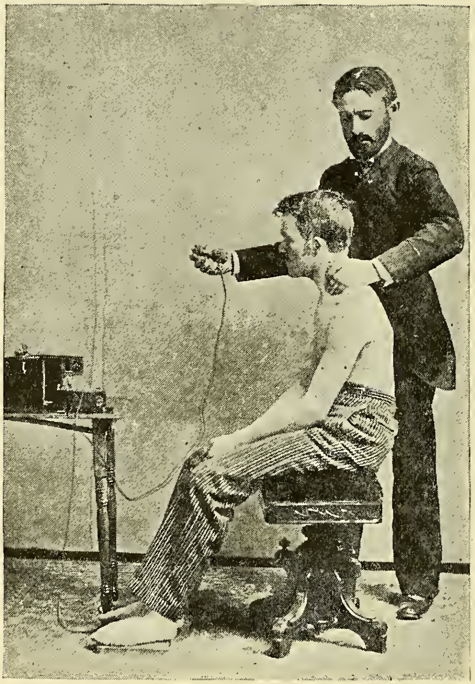

FIG. 106.—General Faradization. Application to the brachial plexus by the hand of the operator. Treatment by this method is not only unattended with painful sensations, but is absolutely agreeable in its immediate effects upon the patient. The flexibility of the hand, its power of adaptation to every inequality of surface, renders it far superior in applications over sensitive areas to any artificial electrode that human skill can devise.

sixth and seventh cervical vertebræ, and moved slightly on either side of the spine, while a powerful current is passing, the electric influence may be perceptibly communicated, not only to the spine but also to the larynx through the laryngeal nerves; to the stomach through the pneumogastric; to the lungs through the phrenic; to both arms and hands through the brachial plexuses and their branches—in short, to the most important nerves and organs of the body. The sympathetic is also directly affected at this point.

There is no other single place on the surface of the body where the electric influence can be communicated to so many important nerves as at the cilio-spinal centre. In order, however, to affect all these nerves and organs above mentioned by faradization, it is necessary to use a powerful current, and to press the sponge very firmly against the skin.

In very fleshy patients it is sometimes quite difficult to affect the brachial plexuses and their branches in the arms and hands without using a stronger current than can well be borne through the feet and ankles at the negative pole. This application, so far from being painful, is to many positively agreeable. The thrill which it communicates to the nerves and vital organs is often so delightful that the patient requests to have the application prolonged. In patients who can bear it, this application at the cilio-spinal centre may be varied by suddenly interrupting the current.

This application is a very important factor in general faradization, and will achieve decided tonic effects on the system, even when no other portion of the body is touched by the current. The immediate sensations which it produces, however, are by no means uniform. Some patients, through the irritation of the laryngeal nerves, cough spasmodically, and even violently, under the excitation even of a comparatively mild current; with others, even the most powerful currents, and the firmest possible pressure of the sponge, fail to produce any such effect. In nervous and sensitive patients this application often causes a peculiar and decided sensation in the stomach, through the pneumogastric nerve; the strong and vigorous rarely experience any such sensation, even under currents of great power.

Another important locality in the electro-therapeutic anatomy of the neck is in the posterior triangle, just by the posterior border of the sterno-cleido-mastoid muscle. If the fingers of the operator, with a current of considerable strength, or the sponge with a current comparatively mild, be pressed firmly on this space until the posterior border of the scalenus anticus is reached, the patient will at once experience a tingling or pricking sensation in the arm and hand on that side, caused by the excitation of the brachial plexus, and in some cases a thrill is communicated by means of the pneumogastric to the stomach, and by the phrenic nerve to the diaphragm.

Applications to the Upper Extremities.—It is not always necessary to go to the trouble of faradizing the extremities, but in many cases it is a decided advantage to do so. In faradization over the extremities, the sponge, or the hand of the operator, should be passed thoroughly over the surface of the hands and arms, and with sufficient force to produce agreeable contractions of all the superficial muscles. Except in infants and corpulent females, contractions of the superficial muscles of the arm are obtained with a mild current.

Applications to the Spine.—Stronger currents of electricity may be borne over the middle of the spine than perhaps over any other portion of the body. There are no very sensitive peripheral nerves in the back, and the spinal cord is so thoroughly protected by its bony covering that the currents are never felt in it painfully, except when it is greatly exhausted or organically diseased. The nerves that issue from the spinal cord are more or less affected by powerful applications to the back, and through them the various parts and organs which they supply are considerably influenced.

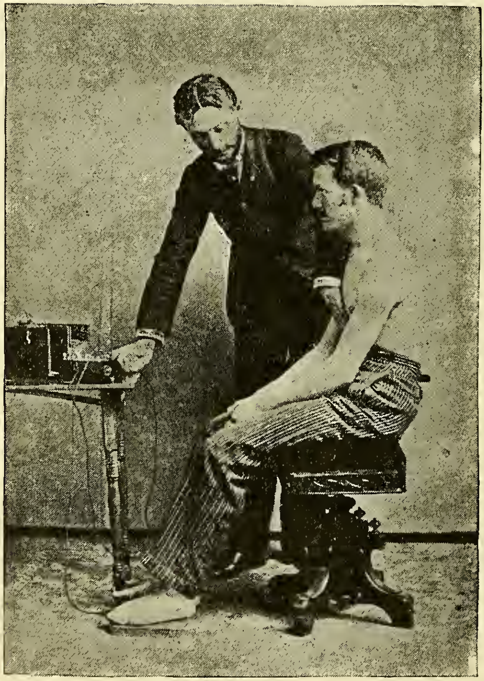

FIG. 107.—General Faradization. Application to the stomach.

The best method of electrizing the back is to pass the sponge down its entire length beneath the under-clothing, in case it is not removed, from the first cervical vertebra to the cauda equina, carefully avoiding the prominences of the scapula and the ossa innominata. Below the inferior angle of the scapula the sponge may be moved from side to side over the region of the kidneys, liver, and spleen.

If a strong current be applied over the lower portion of the spine, between the upper borders of the ossa innominata, a slight sensation is sometimes, though by no means uniformly, communicated to the rectum and the male genital apparatus, the penis and the testicles, through their spinal nerve supply.

In view of these considerations it is manifest that in the employment of general faradization particular attention should be given to the spine, even at the expense of neglecting other portions of the body.

That the lungs and heart are less influenced by electrization than other important organs, is chiefly accounted for by the anatomic structure of the chest. The ribs, with the intercostal muscles and ligaments, form an unyielding wall. Furthermore, the pleura and pericardium are not closely

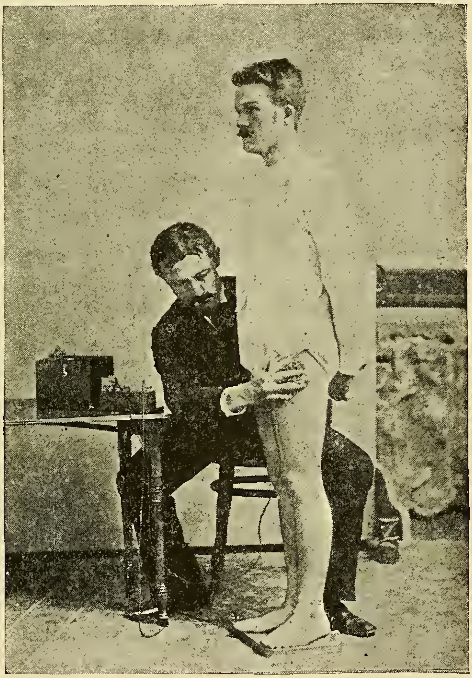

FIG. 108.—General Faradization. Application to the lower extremities.

adherent to the inner wall of the chest, but lie loosely over the lungs and heart. These organs, therefore, are best affected electrically by applications above the sternum, around the neck, and over the upper half of the spine, whence the nerve-supply of the viscera proceeds, and by direct electrization of the vagus in the neck.

Applications over the chest are, however, of positive and permanent service, by developing the thoracic and intercostal muscles, and for this reason, if for no other, they should not be neglected. But it should not be forgotten that the surfaces of the rib, like the surfaces of all other bones, are sensitive to electrization, and that therefore the chest will not bear as severe applications as the spine, neck, or abdominal regions. This sensitiveness is, of course, more in the thin and nervous than in the corpulent and phlegmatic. It is usually most marked on the inferior ribs on the right and left side of the body, over the liver and spleen. The peculiar sensitiveness of the ribs at these points is sometimes erroneously supposed to indicate disease of the organs beneath them.

We have stated above that the anatomic structure of the chest rendered it difficult to send the electric current through its anterior walls to the lungs and heart. In the abdominal regions the anatomic structure is directly reversed, and instead of an unyielding wall, partly composed of bones and ligaments, we have a flaccid skin lying loosely against the peritoneum that covers the moist viscera beneath. No other organs of the body contain so large a percentage of water as those which are situated in the cavity of the abdomen. It is obvious, therefore, that when the resistance of the epidermis is overcome by the moisture of the sponge or hand, and the peritoneum and viscera are brought into coaptation, the current must directly traverse all the parts desired to be affected.

To reach the stomach and solar plexus, place the sponge or palm of the hand below and under the sternum, and as far back as possible. This pressure brings the peritoneum and stomach into coaptation, and forces the current to pass through them. If the under-clothing be simply slipped up without being entirely removed, the stomach and abdomen can be readily treated.

The bowels may be treated either with the labile or the stable current, and, in cases of obstinate constipation, by sudden interruptions or shocks.

Corpulent and pursy patients usually bear much stronger currents over the abdomen than the thin and emaciated. Adipose tissue is comparatively a poor conductor of electricity, and it is difficult to affect the bowels of the very corpulent through the abdominal walls by electrization, unless we employ firm pressure and currents of considerable strength. But in the vast majority of cases currents of moderate strength, applied lightly over the surface of the abdomen, will readily produce contractions of the abdominal muscles, and, if pressure be employed, the intestines and all the organs of the abdominal cavity are directly traversed by the current.

Applications to the Female Genitals.—Direct applications to the vagina or uterus are rarely called for in general faradization.

Applications to the Lower Extremities.—Unless there is weakness or paralysis of the lower limbs we do not always apply the current directly to them, because, when the copper plate is at the feet, the muscles below the knee are more or less exercised during the whole treatment.

Before proceeding to make the applications to the lower extremities, the patient should be required to stand up, still keeping the feet on the copper plate. Male patients who, during the earlier stages of the operation, have entirely removed their clothing from the trunk, should be allowed to again put it on, both in order to avoid unnecessary exposure and to protect them from the cold.

With female patients the applications to the lower limbs, except in cases of paralysis, can be made under the clothing, if the drawers be slipped down, without exposure.

The operator, sitting by the side of the patient, or on a low stool or ottoman, should then pass the sponge or the hand lightly down the entire surface of both limbs, from the thighs to the feet, avoiding, so far as possible, the prominences of the bones at the hip, knee, and ankles.

The outer portion of the thigh, like the back, is very little sensitive to the electric current, because its surface is not supplied by very sensitive nerves. The inner side of the thigh, on the contrary, is supplied by branches from the sensitive anterior crural nerve, and in nervous persons especially is very susceptible to electrization. In passing the sponge or the hand down the lower limbs great pains should be taken to carefully graduate the current according to the sensitiveness of each locality. This precaution is more necessary in treating the lower limbs than the upper, because the contrasts in the normal sensitiveness of the different parts of the lower limbs are much greater than in the arms, and because any severe shocks suddenly felt in the legs sometimes throw patients off their feet.

In cases not complicated with paralysis, contractions of the superficial muscles of the lower limbs, as of the upper limbs, can be produced by comparatively feeble and painless currents.

Special Rules to be Observed in the Employment of General Faradization.—In the employment of general faradization there are certain special suggestions, on the observance of which the results of the applications will very materially depend.

1. *The Strength of the Current and Length of the Application.*—It is better that the first tentative applications should always be made with a gentle current, and, if the patient be particularly sensitive, it is an advantage to use the hand of the operator instead of an artificial electrode. After the patient has become somewhat accustomed to the treatment, the general rule should be to make the applications pleasantly painful.

Patients who have long been accustomed to the treatment—who have become, in a certain sense, insensible to the strength of current ordinarily used—may frequently be benefited by very powerful currents.

Usually, but not invariably, we may be guided by the sensations of the patient; but exceptions to this rule are sometimes very striking, and should put us on our guard. Some who feel no pain during the applications may on the day following experience the most disagreeable reactive effects.

2. *Thoroughness of the Application.*—General faradization does not require that all portions of the surafce of the body should be touched by the

electrode at every sitting. In nervous and susceptible patients we can approach the full measure of the treatment only by slow degrees. It is oftentimes sufficient to make the first application only around the neck, shoulders, and on the upper portion of the spine.

It is not always necessary to make the applications to all portions of the surface of the body, even in a prolonged course of treatment. The general tonic effects of this system of treatment can undoubtedly be achieved without touching either the upper or lower extremities. But, on the other hand, it is just as undoubtedly true that the muscular development that results from long-continued electrization of the arms and legs reacts favorably on the whole system and materially aids the treatment.

The neck and spine should be treated in all cases, except during the first and tentative applications, or in patients of very unusual susceptibility. During menstruation it is usually better to avoid the abdomen and lower part of the spine, or to suspend the treatment altogether, except in those cases where it is desired to increase the menstrual flow.

Length of the Applications.—The duration of the sittings may range between five and twenty-five minutes, being modified by the nature of the constitution, the strength of the current employed, the stage of the treatment, and the results of the previous applications.

The smallest fraction of this time should be devoted to the head, the largest to the spine; next to the spine the abdomen should receive the largest share of attention.

An average application of say 15 minutes may be thus apportioned:

To the head	1	minute.
" neck, sympathetic and cervical spine	4	minutes.
" back	3	"
" abdomen	3	"
" upper and lower extremities	4	"

As compared with the time required in localized faradization and central galvanization, general faradization has not the great disadvantage that has been supposed. Nearly all the ordinary peripheral applications of electricity for paralysis require as much time as general faradization.

Frequency of the Applications.—The applications of general faradization may be repeated daily, every other day, once or twice a week, or by still longer intervals. Every other day is about as often as is necessary to secure the full tonic results of the treatment; but patients who are so situated that they can take the treatment but a short time may receive an application daily, provided they are not in a condition of unusual debility, or are not more than ordinarily susceptible to the current. For the very nervous and susceptible, and especially for those who complain of the secondary or reactive effects, it is often necessary to give intervals of several days, at least until the permanent tonic effects begin to be developed.

Persistence in the Treatment.—For the majority of cases, the treatment by general faradization, in order to secure its full results, must be persistent. The reasons why this perseverance is demanded are quite obvious. In the first place, most of the diseases and morbid conditions for which general faradization is indicated are exceedingly chronic in their character. It is necessary ever to keep in mind the emphatic words of the great Trousseau, "Chronic diseases demand chronic treatment," whatever may be the method employed.

Secondly, tonic remedies of all kinds, external and internal, are always more or less slow in their action.

While great and beneficial effects are often derived from two or three applications, a complete or approximate cure of long-standing morbid conditions, such as dyspepsia, hypochondriasis, nervous exhaustion, hysteria, paralysis, can only be achieved by persistent treatment, varying the strength of the current and frequency of the applications according to the progress which is made.

The length of time over which the treatment should be extended may range from one week to several months, with longer or shorter intervals, according to circumstances.

Comparing the history of all our cases, we find that the average number of applications administered to each successful case is about 15–25, and the length of time over which the treatment was extended 4–8 weeks.

The Use of the Moistened Hand as an Electrode to the Head and Sensitive Parts.—The advantages which the moistened hand sometimes possesses over the sponge in general faradization are the following:

1. In certain cases it is more agreeable to the patient. It is but a truism to assert that no form of electrode that human skill shall ever devise can ever compare with the hand in flexibility and power of adaptation. Its shape, its flexibility, the number and arrangement of the fingers, and the vast and delicate combinations of movement of which they are so readily capable—all these familiar and wonderful characteristics of the hand, united to the peculiar softness of the skin, and the lightness with which it can touch, or press, or handle, render it superior for the nicer processes of general faradization to any artificial arrangements of which the genius of man could conceive.

For applications to the head and sides of the neck, the brachial plexus, and all sensitive areas, the use of the hand electrode is a very great convenience; and we sometimes meet with patients who are so sensitive and so fearful that they will not endure even the softest sponge on any portion of the body, or at any stage of the treatment. To apply a mild faradic current to the forehead and crown of the head, with the softest sponge and largest possible surface, is at best an unpleasant process for a strong man in perfect health, and for the delicate invalid is often unendurable; but when the hand of the operator is made an electrode, the operation of faradizing the most sensitive portions of the head may be made not only tolerable, but positively agreeable. Except in cases of severe local disease or unusual debility, the sponge can be borne down the spine, over the abdomen and extremities, and down the lower extremities without great difficulty.

2. It keeps the operator continually informed of the strength of the current, and thus enables him to carefully graduate it, according to the sensitiveness of each locality.

As the current passes through his own person, the operator can judge by his own sensations whether it is too strong or too weak, and by increasing or diminishing the grasp of his other hand on the sponge, can modify the strength of the application without disturbing his apparatus. The wet sponge on which he presses with the other hand acts, as we have seen, like a hydro-rheostat.

The use of the hand as an electrode enables the operator to instantly modify the applications in any of the various degrees of weakness and strength, and also to suspend the passage of the current instantaneously without shock or violence. When the sponge is used we must continually question the patient, or watch his expression and movements, in order to judge whether the current is of proper strength.

That most, if not all, of the tonic effects of general faradization can be obtained in perhaps the majority of patients by the use of the sponge, there can, we think, be no question; but the use of the hand of the operator, according to the principles above indicated, enables us to achieve these results, and with less discomfort to the patient, in those peculiarly sensitive cases where the artificial electrode could not be borne at all. Very many of our patients we treat only with artificial electrodes.

To sum up, in a word, it is a convenience and oftentimes a positive assistance for the operator to be able and willing to use his hand in applications to sensitive parts and nervous patients, but for the majority of cases it is sufficient to use a large soft sponge.

Effects of the Current on the Operator.—The question now arises, What effect must the operator experience from the repeated passage of the electric currents through his own person?

It should be understood, at the outset, that the current does not directly affect the whole person of the operator, nor indeed any of the prominent organs, and that only the faradic current is used in this way. The current passes from hand to hand, through the arms and shoulders, and does not reach or directly influence the brain or any of the organs of the chest or of the abdomen. The effects of thus using the current on the nutrition of the muscles of the arm have already been considered (see Electro-Physiology).

Those physicians whose temperaments do not tolerate electricity, would do well to avoid passing the current through their own persons in this way. Those, however, and they constitute the majority, who are more or less benefited by the use of electricity in this way, need never fear any evil effects. If they treat a very large number of patients a day by general faradization, using the hand as an electrode a considerable portion of the time, and with strong currents, they will be much more wearied at night than if they used the sponge chiefly or exclusively. This method of general faradization has been and is now used by hundreds of physicians, and we have never heard of any serious effects in any in stance. The few whose temperaments contraindicate electricity soon abandon the use of the hand as an electrode, since they find that it is a luxury and not a necessity. The majority experience either negative or beneficial effects, and arrive at that state where it is a matter of indifference whether they use the hand or sponge.

Special Effects of General Faradization.—The general effects of electricity on the system have already been considered. We have here to speak only of those that are peculiar to or most marked under general faradization.

The effects of general faradization may be subdivided into three classes:

1. Those which are experienced during or immediately after treatment—primary or stimulating effects.

2. Those which are experienced one or two days subsequent to the treatment—secondary or reactive effects.

3. Those which remain in the system as a permanent result of treatment—permanent or tonic effects.

Many patients, perhaps the majority, experience after each *séance* a feeling of enlivenment and exhilaration that often lasts for several hours. With some this feeling of exhilaration is very positive and decided; with others it is but just perceptible. Others, again, experience a disposition to sleep after treatment, quite similar to that which is felt after a bath in the surf.

Relief of pain and local or general weariness is a very frequent as well as very agreeable temporary effect of general faradization, and one which, more perhaps than any other, tends to inspire the doubting patient with confidence in the efficacy of this method of treatment. Patients who suffer from indefinable nervous pains in the head, back, side, and stomach, or from weakness in the limbs, frequently appreciate relief even in the midst of the application. This relief usually lasts for several hours, and in some cases may become permanent.

All the disagreeable symptoms that sometimes arise from an application, as headache, malaise, chilliness, vertigo, faintness, and cold perspiration, like similar effects from injudicious use of other tonics, physical exercise, the shower-bath, etc., are not usually of any permanency whatever. Indeed, they are entirely consistent with permanently good results;

but they are apt to annoy and alarm the patient, and for that reason, if for no other, they should be avoided.

Effect on Temperature.—The temperature may be immediately influenced by general faradization.

Its effect on the circulation seems to be that of an equalizer. Patients afflicted with nervous diseases are apt to suffer from cold feet and hands, and from creeping chills over the body. The equalizing, warming effect of general faradization on such patients is most decided and agreeable, and is so positively realized, even in the midst of the *séance*, that neither the bare feet nor the exposed trunk suffer from the cold, provided the air of the operating-room is of even a moderate temperature.

Effect on Pulse.—The effects of general faradization on the pulse are quite interesting and suggestive.

In a large number of cases we have carefully counted the pulse, and also observed its quality just before and just after the treatment. The results of some of these observations are presented below:—

	Before the Application.	After the Application.		Before the Application.	After the Application.
1	60	60	12	68	80
2	77	76	13	104	100
3	88	80	14	68	80
4	74	80	15	70	73
5	60	75	16	106	102
6	82	84	17	72	60
7	80	76	18	72	67
8	76	84	19	74	70
9	80	84	20	68	76
10	101	90	21	72	66
11	115	100	22	74	62

On account of the recognized susceptibility of the pulse, especially of nervous invalids, to the influence of mental impression, we have found it necessary, in order to avoid error, to make repeated examinations before and after the sitting.

The conclusion, from our very large number of observations in regard to the influence of general faradization on the pulse in chronic diseases, is that of a corrective.

When the pulse is high it depresses it more or less, and usually in proportion to the degree of the exaltation above the normal standard. When it is low it raises it more or less, and usually in proportion to the degree of the depression below the normal standard. In nervous and excitable patients, the effect of general faradization on the pulse is much more marked than in the cold and phlegmatic. An application that is much too strong may greatly excite the pulse.

Special and Exceptional Effects.—The immediate effect on the appetite is, in rare instances, so marked that the patient at once feels desire for food, and at the next meal eats a much larger quantity and with far keener relish than usual.

Sensitive patients are now and then compelled to evacuate their bladder or rectum immediately after or even in the midst of the application, and the urinary secretion is occasionally increased. But all these effects of general faradization on the functions of special organs are incidental and occasional, and are not to be expected with any uniformity or constancy.

Secondary or Reactive Effects.—The secondary or reactive effects of general faradization are those which are experienced for a day or two following an application. These effects are probably not observed in more than half of the cases, and usually only at the outset of the treatment. Most of these secondary or reactive effects have already been considered.

Soreness in the muscles of the neck, trunk, and upper extremities is unquestionably the most frequent of the secondary symptoms of general faradization, and the one which patients are soonest to observe and describe. It is the result of the muscular contractions that are produced by the electric current. It usually passes off in two or three days, and is scarcely observed at all after the patient has once become accustomed to the treatment. By making the first tentative applications gentle and short, it is possible to avoid entirely this subsequent muscular soreness, and in very feeble or very timid patients we should always endeavor to do so.

Indefinable nervousness is another occasional secondary effect, and one that often gives rise to idle and unnecessary alarm. Like the soreness of the muscles, it usually passes off in a day or two, and is not commonly experienced after the patient has become accustomed to the treatment.

Weariness and exhaustion may be experienced by this class of patients for several days after an injudicious application. It is a very interesting and important fact that these annoying secondary symptoms of weariness and exhaustion are oftentimes experienced to their fullest extent by patients on whom the immediate effects for a few hours succeeding the application are only agreeable. On account of this fact, the inexperienced electro-therapeutist may be unpleasantly deceived, and from the temporary enlivenment of his patient may suppose that his application has been thoroughly successful, until the distressing secondary effects, continuing perhaps for several days, show most clearly that it has been either too strong or too protracted.

Permanent or Tonic Effects.—To designate any precise time or stage of the treatment when these tonic effects are to be looked for is manifestly impossible. Like the tonic effects of other analogous internal or external remedies, the time of their appearance must be variously modified by the nature of the disease, the constitution of the patient, and the skill and perseverance of the treatment. They may appear early in the treatment, developing themselves with great rapidity; or they may remain latent until after the applications are abandoned, and then advance with sure and steady progress. They may be so rapidly manifested at the commencement of the treatment as to cause us to suspect them to be more the result of mental impression than of the applications; and, on the other hand, they may develop themselves so long after the treatment as to suggest the doubt whether they are not as much due to nature and time as to the direct electric influence.

Among these tonic effects of general faradization, those which chiefly attract the attention and are of the principal importance are the following:

Improvement in the Sleep.—This symptom comes first in our analysis of the permanent effects of general faradization, because it is one of the first to be appreciated and observed by the patient. As insomnia is the most constant and universal symptom of those various nervous conditions for which general faradization is indicated, just so is its relief or cure the first and leading evidence that the treatment is having its desired effect. As already mentioned, inclination to sleep is one of the immediate symptoms of the applications, and may come on even in the midst of the *séance;* but the improvement in the sleep of which we here speak, as a permanent effect, is appreciated during the intervals of treatment, and long after it has been suspended.

Increase of Appetite and Improvement in Digestion.—Increase of appetite and improvement in the digestion is not so early nor so constant a symptom as improvement in the sleep.

It is by no means a constant or uniform effect, even in those cases where it would seem to be needed, and where, too, in all other respects, great and lasting benefit is derived from the treatment. Some patients who are permanently relieved of neuralgia, of insomnia, and of muscular and nervous debility, yet observe no decided improvement in their digestion. Such cases, however, are quite exceptional.

Regulation of the Bowels.—Constipation sometimes yields very early in the treatment. The temporary effect is probably due, in many instances certainly, to the direct mechanical action of the current on the intestines; but permanent relief, either of constipation or of diarrhœa of the nervous variety, is not to be expected until the indigestion and general debility on which they depend have first been corrected.

Improvement in the Circulation.—Permanent equalization of the circulation is most observed in cases of dyspepsia, nervous exhaustion, hysteria, and similar conditions with which defective circulation is so frequently associated. It is then the result of the improvement in the assimilative power and nutrition of the system.

Relief of Nervousness and Mental Depression.—The indefinite, though very well recognized condition which we term nervousness, and the indefinable mental agony that forms so prominent and so distressing a symptom in hysteria, dyspepsia, exhaustion, and other nervous conditions, sometimes yield to general faradization quite early in the treatment.

Increase in the Size and Hardness of the Muscles and in Weight of Body.—This is a natural result and accompaniment of the improvement in nutrition, and that it follows the use of the faradic as well as of the galvanic current, sufficiently demonstrates that power over nutrition is not confined to the latter.

Under the influence of protracted treament by general faradization, the muscles are sometimes developed in size as well as in firmness to a degree which very naturally astonishes those who, for the first time, have their attention directed to it. This increase in size and quality of the muscles is, of course, chiefly observed in those portions of the surface of the body where, under the influence of faradization, contractions are most easily produced. Therefore we first look for this effect in the arms, the legs, and afterwards in the chest. This effect is soonest observed in patients who are comparatively thin, or at least whose muscular tissue predominates over the adipose. On the other hand, and for obvious reasons, it is not so perceptible in females, or in the very corpulent of either sex.

Under general faradization actual increase in the size and weight of the body sometimes takes place so rapidly and perceptibly to the eye that it need not be confirmed by reference to the scales. In other cases, where patients, either through curiosity or accident, have carefully weighed themselves just before taking a course of treatment, a most remarkable increase of weight has often been observed in the course even of a few weeks.

The increase of weight is simply a result of the effect of the electric currents on nutrition, and a natural sequence of the improvement in the sleep, the increase of appetite, and the relief of pain and mental depression of which we have already spoken.

Increased Disposition and Capacity for Labor of the Muscles and of the Brain.—Whatever tends, directly or indirectly, to improve nutrition must of necessity increase the capacity for intellectual and muscular toil. Accordingly we find that patients who were so feeble that even a short walk or ride was fatiguing, and who were signally deficient both in the will and the capacity for exertion, soon begin to develop, under treatment, an activity and vigor that is sometimes surprising. They can walk farther and more vigorously, and with greater enjoyment. They realize a consciousness of strength to which before they were strangers, and feel emboldened to exertion from which they would formerly have shrunk with apprehension.

Concerning these permanent tonic effects it is to be observed:—

1. They are not uniform. They vary not only with different individ-

uals and diseases, but also with the same individual at different periods of life.

2. They are more rapidly appreciated by the active and the nervous than by the cold and phlegmatic. Other conditions being the same, a sensitive, impressible organization will recover more rapidly under general faradization than one of an opposite temperament.

3. They are frequently not experienced until long after the treatment is abandoned. These after-effects of general faradization are worthy of the highest attention. The possibility that they may occur is a constant encouragement in the treatment of all slow and obstinate cases.

4. They are usually as lasting and permanent as similar effects from other remedies and systems of treatment. It is true that patients who have been apparently cured by general faradization are subject to relapses, yet to no greater and apparently to a less extent than those who have derived similar relief from internal medication. In considering this statement, regard should be had to the fact that the diseases for which general faradization is chiefly indicated, at least those in which it has thus far been most successful, are just the diseases which are most likely to relapse under any or all forms of treatment.

Rationale of the Effects of General Faradization.—It has been said of general faradization that it is not physiologic; but they who raise this objection do not well consider what they say. Of the various methods of electrization none can be better explained on a physiologic basis than can this. General faradization is to the whole body what localized faradization is to an individual part or organ. All the physical, mechanical, chemic and physiologic effects, with the consequent increase of the processes of waste and repair and improvement in nutrition that electrization is capable of producing in the living tissues (see Electro-Physiology) and which, in exclusively localized applications, are mainly confined to the part which is traversed by the current, are in general applications appreciated by every part of the system. Then, again, the improvement which each part or organ receives from the treatment reacts upon every other part and organ. Every effect becomes in its turn a cause; the strengthened brain sends more nervous force to the stomach, by which the latter is enabled to send better blood to the brain.

Comparing what is known of the conductibility of the tissues and the action of the electric currents upon them, with the observed effects of general faradization, these effects may be regarded as due mainly—

1. To the fact that the nutrition of the entire central nervous system is directly influenced by the current. In an ordinary application the brain, spinal cord, and sympathetic ganglia are all subjected to the action of the current. In most of the applications of central localized electrization only a part of the central nervous system is affected at each sitting.

We are warranted in believing that in nearly all nervous diseases the central nervous system is more or less disturbed, even when it is not organically diseased.

2. The passive exercise that results from the vigorous and repeated muscular contractions produced by the applications. When the applications are thoroughly and skilfully made, vigorous yet agreeable contractions are excited, not only in all the superficial muscles, but in the deeper layers, and also of the contractile fibre-cells of the stomach, the intestines, and other vital organs. The augmentation of the manifold processes of waste and repair which a single sitting causes in the muscles and abdominal organs would alone powerfully influence nutrition, even though the electric current exerted no direct effect on the nervous system.

That the tonic effects of general faradization are very largely due to the passive exercise which it produces is proved clinically by the fact that when a current too feeble to cause muscular contractions is used, or when the muscles are neglected, the tonic as well as the primary effects of the treatment are much less marked.

3. Reflex action from the sensory nerves. The reflex effect of the faradic current even is very powerful, and in general faradization nearly all the superficial sensory nerves are acted upon, and consequently the whole nervous system is constantly under reflex as well as direct influence of the current.

CHAPTER XI.

DIFFERENTIAL INDICATIONS FOR THE USE OF LOCALIZED AND GENERAL FARADIZATION.

In order to determine the differential indications for the use of localized and general faradization we need to consider these four facts:

First, that general faradization directly affects the whole body, while in localized faradization the direct action of the current is mainly confined to the part to which the application is made.

Secondly, that general faradization may, by sympathetic or reflex action, indirectly have a special therapeutic influence on some special part or organ, while localized faradization of any part, but especially of the sympathetic or cerebro-spinal axis, by sympathetic or reflex action, may indirectly have a general therapeutic influence on the whole body.

Thirdly, faradization, when properly performed, very rarely injures, and usually more or less benefits, even those parts which are in comparative or absolute health. This consideration has an important practical bearing, especially in the use of general faradization, in cases of doubt as to the seat of the disease.

Fourthly, in nearly all cases it is important, and in many it is indispensable, that the applications should be made to the seat of the disease as well as to the locality of the symptom. Scientific electro-therapeutics, therefore, requires the most accurate preliminary diagnosis; above all, it is important to rigidly discriminate between diseases which are of a constitutional and those which are of a local origin.

From these fundamental considerations we logically derive the general law that constitutional diseases are better treated by general, and local diseases by localized, faradization.

More specifically, experience demonstrates that of the large variety of diseases for which applications of electricity are found useful, localized faradization and galvanization are specially indicated in those cases where both the seat and the effects of the disease are restricted to certain portions of the organism, with but slight or imperceptible influence on the system at large. Under this head are included nearly all peripheral and reflex paralyses and neuralgias, effusions, sprains, and local injuries, and also many of the diseases of the eye, ear, larynx, and genital and digestive organs.

On the other hand, general faradization is indicated:

1. In those diseases that are dependent on or associated with impairment of nutrition and general debility of the vital functions, such as nervous dyspepsia, neurasthenia, anæmia, hysteria, hypochondriasis, paralysis, and neuralgia of a constitutional origin, rheumatism and other toxic diseases, some forms of chorea, and oftentimes in functional disorders of the genital, digestive, and other special organs.

2. In morbid symptoms dependent on some local cause which cannot be satisfactorily diagnosticated. It must be confessed that a large number of cases of chronic diseases are frequently dependent on or connected with some important lesions, of which, during the lifetime of the patient, even the most approved methods of diagnosis and the most practised skill utterly fail to ascertain either the nature or the locality. This is oftentimes the case with epilepsy, hysteria, and hypochondriasis; sometimes, also, with affections of special organs, as the eye, ear, larynx, and uterus.

Benedikt emphatically affirms that electricity should be applied almost exclusively *in loco morbi*, in the place of the disease, and in cases of doubt recommends tentative applications successively in all the suspected localities until the diagnosis is made out by the success of the treatment.* It scarcely need be said that this purely experimental system, though sometimes successful, must be and is annoying, uncertain, and very frequently unsatisfactory.

The advantage of general faradization in such cases of doubtful pathology are twofold: First, at each application it affects all parts of the body, and thus is sure to reach the seat of the disease, wherever that may be; and, secondly, it at the same time improves the general nutrition of the system, which in such cases is frequently more or less impaired. This improvement in nutrition, as has been stated, oftentimes reacts favorably on the local disease.

Still further, it must be confessed that very many of the diseases in which general faradization is proved to be of most efficient service, are those in which no special *locus morbi* can be found even on post-mortem examination.

Future investigations will undoubtedly do much to dispel our ignorance on these points, and will probably assign a definite local cause to some of the diseases which are now vaguely classed as constitutional. But even those diseases in which the local cause is definitely ascertained may demand constitutional treatment as much as or more than those in which no local cause is demonstrated. When a house is set on fire by a burning fuse, it is not enough to snatch away the fuse; we must extinguish

* "Die Electrotherapie," Wien, 1868, p. 79.

the flames. When the nervous system has been thrown into tetanus by a wound in the foot, excision or healing of the wound is of little avail; remedies must be directed to the central nervous system. Precisely so when chronic local disease has enfeebled the vital functions and impaired nutrition, our applications are to be directed to the general system as well as to the seat of the lesion.

3. In certain diseases which, though themselves incurable, are accompanied by impairment of nutrition that is susceptible of more or less relief. Palsy agitans, many cases of cerebral and spinal paralysis, advanced stages of locomotor ataxia, rheumatic gout, epilepsy, and certain spastic affections, may be absolutely incurable, and yet the emaciation, nervousness, insomnia, and general feebleness with which these diseases are associated as cause or effect or concomitant, may be susceptible of most grateful relief from general faradization. In not a few cases of disease of these varieties, after we have failed to do any good by galvanization of the brain, sympathetic and spinal cord, after even central galvanization has failed, general faradization alone, given without special reference to the seat of the pathologic lesion, has greatly relieved the symptoms and been of invaluable service by virtue of its tonic effects, although, of course, it could have no permanently curative influence.

Cause of Failures in Electro-Therapeutics.—The comparison we have here made reveals the cause of some of the failures and discouragements that have been and are now being encountered by many experimenters in the department of electro-therapeutics. Constitutional diseases have been treated locally. Morbid constitutional conditions, such as hysteria, anæmia, rheumatism, and the like, which, as all physicians agree, demand remedies that affect the system, are treated electrically only through their local symptoms, such as peripheral paralysis, or neuralgia, or inflammation of the joints. Temporary relief, or metastasis of these local symptoms may indeed result from exclusively localized applications in such cases, but permanent correction of the morbid condition on which these symptoms depend can only be obtained by general treatment. In subacute rheumatism, for example, galvanization or faradization of an inflamed joint frequently removes the pain and effusion in that joint, and therefore may advantageously be used with general faradization, just as the external application of alkaline solutions may advantageously be combined with the internal administration of the same remedies; but to depend on merely localized electrization in such cases is manifestly as unphilosophical as it would be to depend on merely local applications of alkalies. In general practice it will unfortunately be found that physicians will frequently use localized in cases for which general treatment is indispensable for complete results, for the reason that they have neither the time nor the practice to enable them to use the latter method with success; just as the majority of general practitioners, for want of a galvanic apparatus, are obliged to use faradization in cases for which galvanization is imperatively demanded.

Combination of the Methods.—Many cases are most successfully treated by a combination or alternation of the two methods. Thus rheumatism, for example, may be treated one week or one day by general faradization, and the following day or week by local faradization or galvanization of the affected joints.

This comparison furthermore reveals and explains the suggestive fact that the sphere of electro-therapeutics has, in a mesaure, corresponded to and progressed with the advance in the method of application. Thus, when peripheral applications were chiefly used, the scope of electro-therapeutics, though important, was narrow, neuralgia and paralysis being the diseases for which it was mainly employed. On the introduction of localized galvanization of the nerve-centres, electricity was found to be most useful for many conditions in which previously it had been supposed to be either valueless or contraindicated. The sphere of electro-therapeutics is by general faradization and central galvanization and improved methods of static electrification still further extended to embrace a large variety of conditions and indications which localized applications fulfil either not at all or but very imperfectly.

CHAPTER XII.

CENTRAL GALVANIZATION.

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

FIG. 109.—Central Galvanization, first stage. Milliammeter and rheostat intercalated. One pole on the epigastrium, the other on the cranial centre, the hair at that point being moistened. Before making the application at this point the electrode may be passed over the forehead.

The following representations of the principal steps in the method of central galvanization were made from photographs taken during the applications.

A female patient is taken in order to show that this method in its entirety requires little or no exposure.

Details of the Applications.—We do not always make the applications all over the head, but merely on the forehead, gently passing the electrode from one side to the other; then baptize the patient on the cranial centre, at the top of the head, and rest the pole there for about one minute, and sometimes longer. To the head we apply from three to thirty milliamperes—for patients vary in their susceptibility—beginning with a weak current and gradually increasing until a sour or metallic taste is perceived in the mouth. The cranial centre—the summit between the ears—we regard as the most important region of the head in all electric applications,

FIG. 110.—Central Galvanization, second stage. One pole same position as before, or lower down, and the other passed up and down by the inner border of the sterno-cleido-mastoid muscle from the auriculo-maxillary fossa to the sternum.

and especially in central galvanization. A current passing from that point to the epigastrium traverses the centre of life—if life has any centre—and affects the sympathetic and the roots of the facial nerves. The sensation produced by this application is different from that of any other application to the head, and is sometimes indefinable.

An application to this point for one or two minutes is usually about as much galvanization as the brain needs. In exceptional cases, where the hair is thin or the head is bald, we make the applications all over the surface, back and front. In applications to the head, care should be taken to avoid sudden interruptions, or shocks that cause dizziness; the flashes of light before the eyes are of little account, but nothing is gained by producing them, and they are annoying to the patient.

The electrode is then passed down the inner border of the sterno-cleido-mastoid muscle, from the auriculo-maxillary fossa to the clavicle, for the purpose of affecting the pneumogastric and sympathetic. We usually make the application on both sides, and from one to five minutes.

In galvanizing the spine, especial attention is given to the cilio-spinal centre, below the first and seventh cervical vertebræ, which is to the spine what the cranial centre is to the brain. The cervical sympathetic and pneumogastric, as well as the spinal cord, are affected by the current.

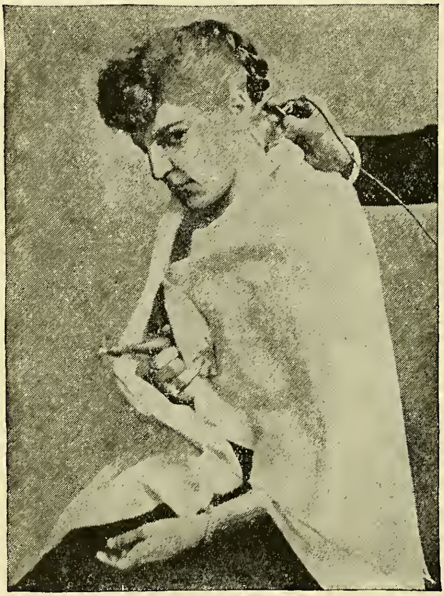

FIG. 111.—Central Galvanization, third stage. One pole same position as before, or on the breastbone, and the other at the back of the neck between the first and seventh cervical vertebræ.

The electrode should also be passed over the entire length of the cord by labile applications up and down. The back is not usually sensitive, and strong currents, from ten to thirty milliamperes, can be borne without any more discomfort than a burning or pricking sensation beneath both electrodes.

The back may be treated from three to six minutes, and the whole length of the *séance* of central galvanization ranges from five to fifteen minutes.

Preparation of the Patient.—All the preparation a male patient requires for central galvanization is to unbutton and loosen the collar, remove the coat and vest, and slip up the whole clothing, so that free access can be had to the spine.

A female patient may remove her corsets and slip up her undercloth-ing, or merely loosen the clothing at the neck and waist, so as to make room for an electrode to be passed down to the epigastrium, and for a spinal electrode to be passed up and down the back.

Electrodes.—For the negative electrode at the pit of the stomach, any sponge or flannel electrode with a broad surface, so as not to be too pain-ful, and an insulated handle that the patient can hold, will answer.

For the positive pole we prefer fine soft sponges of different sizes.

Battery.—Almost any form of galvanic battery will answer for central galvanization, but for reasons before given a battery that gives a steady uniform current, and that is provided with a rheostat, is preferable. The

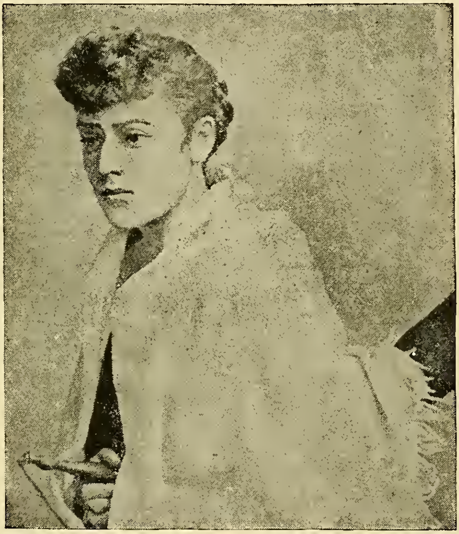

FIG. 112.—Central Galvanization, fourth stage. One pole same position as before, or over the abdomen, and the other passed beneath the loosened clothing, up and down the cord, from the seventh cervical vertebra to the coccyx.

Cabinet battery is exceedingly convenient for central galvanization, but the street current if properly controlled has the advantage of being much less variable in its electro-motive force than any form of battery.

The method of central galvanization is based on these four assump-tions, all of which seem to us justifiable:

1. That in a very large number of diseases, and especially of the so-called functional diseases, the pathology is not exclusively confined to any region of the brain, or sympathetic, or spinal cord, but the whole central nervous system is invaded by a condition of exhaustion and irritability. We believe this to be true not only of hysteria, chorea, and of many affec-tions allied to them, but of certain states of neuralgia and a number of dis-eases of the skin. It is possible, furthermore, that some diseases that

are not now regarded as in any respect of a nervous character may in the future be shown to depend so closely on the nervous system that they can be most successfully treated, not through their varying and local manifestations, but through the brain, spinal cord, and sympathetic. That certain diseases, not primarily nervous, do so affect the nervous system that they need to be treated, in part at least, by remedies that act on the nerves, will be conceded without question.

2. That a large proportion of the most frequent and distressing chronic diseases, as hysteria, hypochondria, neurasthenia, chorea, epilepsy, nervous dyspepsia, neuralgia, and many forms of insanity, are so obscure and subtle in their pathology that it is impossible to determine the precise seat of the disease in any given case, even where some local pathologic condition may exist, and consequently we can never know just where the current should be localized. Even when the seat of the disease is, or is supposed to be, accurately known, if a special revelation should kindly inform us whether epilepsy, for example, takes its origin in the brain or in the sympathetic, and should point out to us just where the lesion occurred, we should still be in the dark in regard to the best method of localizing the current, for without another and still more complex revelation we could not determine the extent to which all other parts of the nervous system had been affected by the local disease.

The force of this objection to the use of the accepted method of galvanizing the brain and cervical sympathetic is seen when we attempt to give the complete pathology of any of the diseases we have just mentioned, and, indeed, of almost any nervous disease that can be mentioned. Where is the precise seat of the disease in nervous dyspepsia? We know that the stomach is weak, and we prescribe galvanization of the pneumogastric; but what have the solar plexus and the spinal cord to say in the matter? Who can tell just how not only they, but the brain itself, may be the origin of nervous dyspepsia, or how much they share in the pathologic disturbance, and consequently how much they need treatment? After eleven centuries of medical study, who can tell the precise and exclusive seat of the disease in epilepsy, hysteria, and neurasthenia? Is not the probability continually growing stronger with the advance of science, that in these and many other diseases the whole or a large part of the central nervous system shares as a cause, or result, or concomitant? Even in those diseases where the lesion is understood, is there not much more of the unknown than of the known? In locomotor ataxia, progressive muscular atrophy, spinal congestion and irritation, is the spine only at fault? Do the sympathetic and brain wholly escape the infection? "Evil communications corrupt good manners" in pathology as well as in morals, and the communications between the sympathetic, and cord, and brain, and the nerves that branch from all these, are so varied, and intimate, and complex, that when the cord is known to be diseased we very naturally incline to consider the other parts of the nervous system, like "poor dog Tray," in bad company, and we become very justly suspicious of their character. In this suspicion we are justified by the accepted views of the functions of the sympathetic, and by the clinical signs and symptoms of these diseases.

In cerebral hemorrhage we usually know the general locality of the disease, if not its precise nature; but the spinal cord, through disuse, becomes affected with secondary degenerations, and the organs of digestion also more or less sympathize.

3. That the nutrition of the central nervous system will be improved by passing through it a mild galvanic current.

That in the great majority of cases of so-called functional nervous disease, and in many of the cases of special structural lesions, nerve-tonics are indicated, will be questioned by no one. It is also coming to be pretty generally admitted that electricity is something more than a stimulant—that it is a tonic with a powerful sedative influence. Still further, it is admitted that the sedative and tonic effects of electricity can be obtained by passing the current, with little or no interruption, through any part, the nutrition of which needs to be improved.

4. It is impossible to exclusively localize the current in the cervical sympathetic, hence it is certain that the good results that in some instances follow the galvanization through the neck are due to the effect of the current on the spinal cord or pneumogastric, as well as to the cervical ganglia of the sympathetic. That the beneficial effects of galvanizing the neck in cases of nausea, dyspepsia, and gastralgia, are due in part if not entirely to the effect of the current on the pneumogastric, is more than probable. Conversely, we find it impossible to tell how far our attempts to localize the current in the pneumogastric, by placing one pole at the pit of the stomach and the other by the inner border of the sterno-cleido-mastoid muscle, was successful; and whether the benefit derived took place through the pneumogastric, the sympathetic alone, or through both combined, seems beyond the power of mortal skill to determine.

Similar difficulties are experienced in the attempt to differentiate the effects of galvanizing the brain; how much the results of applications to the head are due to the direct or reflex action of the current on the brain itself, how much to its action on the cephalic ganglia of the sympathetic, and how much to its action on the roots of the pneumogastric and the upper part of the spinal cord, seems in the present state of the sciences of anatomy and physiology absolutely impossible to determine. In galvanizing the spine we are puzzled by the same complications. The cervical, thoracic, and abdominal ganglia of the sympathetic, with their enormous plexuses, are all liable to be affected by the current whenever it is applied up and down the spine; and how far the beneficial results of galvanization are due to the effect of the current on the cord itself, and how far to its effect on these ganglia and plexuses, only a special revelation can determine.

Still further, the subject is complicated by the consideration that electricity works powerfully by reflex action, and in galvanizing the brain, the cervical sympathetic, or the spine, reflex action must continually take place through the nerve-centres, and the therapeutic results produced by such treatment must be in part attributable to such reflex action.

The positive pole (anode) is applied over the head, neck, and spine, because it is less irritating than the negative, and tends to diminish irritability. The majority of the cases for which central galvanization is used are in a condition of abnormal irritability, and need the calming effects of analectrotonos rather than the irritating effects of catelectrotonos. To this rule there are individual exceptions: there are cases that appear to be benefited more by the negative than the positive pole.

The negative pole (cathode) is placed at the epigastrium, because the epigastrium is a good, indifferent point, that will bear well the irritating effect of catelectrotonos. In order to avoid over-irritation, it is well, in very sensitive patients and when long applications are used, to change the position of the negative electrode by moving it up and down between the sternum and abdomen.

The positive and negative modifications that take place at the breaking of the galvanic current, in the region of the anode and the cathode, probably complicate somewhat the effects of treatment—are, indeed, factors of some importance in producing the effects, and not unlikely explain, in part, the disagreeable results that come from too frequently interrupting the current when treating nerve-centres. The positive and negative modifications can, however, be mostly avoided by using a rheostat of some kind, and gradually reducing the strength of the current to a minimum before the electrodes are removed.

Central Galvanization Compared with Localized Galvanization of the Nerve-Centres.—We claim for central galvanization a distinct and separate position among the different methods of using electricity in medicine. The applications of the galvanic current to the head, the neck, and the spine, which have been variously used by electro-therapeutists since the time of Remak, are simply forms of localized electrization, since the object aimed at in all of them is to localize the current, as far as possible, in the brain or some portion of it, in the cervical ganglia of the sympathetic, or in the spinal cord. Then, again, in all these forms of localized galvanization of the nerve-centres, the poles are placed near each other over the part to be affected, and the peculiar action of both poles is felt, so far as is possible by external application, in the organ that is treated.

In galvanizing the head, for example, the poles are applied behind the ears, or in front of them, or one is placed on the forehead, and the other on the occiput, or at the nape of the neck. In galvanizing the cervical ganglia of the sympathetic, one pole is placed on the auriculo-maxillary fossa, or along the inner border of the sterno-cleido-mastoid muscle, while the other is applied at the back of the neck. In galvanizing the spine, one pole is placed at the upper or lower part, while the other is passed up and down the entire length, or kept in one place, or both may be moved up and down the entire length of the cord, or confined to any portion, as is desired.

But in central galvanization the electrodes are so placed that the whole central nervous system is brought under the influence of one pole (usually the positive) of the galvanic current at one sitting, and without any important change of position of the negative pole. Besides the central nervous system, the pneumogastric and the stomach itself are also affected; in a word, the great centres of life, of health, and of disease.

Comparing central galvanization with localized galvanization of the nerve-centres by the effects, we find differences of a most marked and interesting character exist. The ordinary methods of galvanizing the cervical sympathetic, the brain, or the spine, do not, either singly or in combination, produce the powerful tonic results that are frequently obtained by central galvanization. Sedative and tonic effects are unquestionably produced by these local methods, but they are frequently inferior in quality and degree to those derived from central galvanization when properly administered. This conclusion is derived from actual trial and observation of cases. Neither the temporary nor the permanent effects of localized galvanization of the brain, of the cervical sympathetic and pneumogastric, or of the spine, are as satisfactory in many cases, even when they are successively used at the same sitting and with the same time and strength of current, as central galvanization.

Still further, experience teaches that the method of central galvanization, in its completeness, is more serviceable than partial or incomplete applications of it. Placing the negative pole on the epigastrium, and the other on the spine, will not accomplish the full effects of central galvanization, although so far as it goes it is a good method, and produces sedative and tonic effects. To confine the attention to the head and neck alone, also, is not sufficient.

Compared with General Faradization.—Comparing central galvanization with general faradization, we find most important differences. In the one only the galvanic, in the other only the faradic, current is used.

In general faradization the application is made not only over the central nervous system, but over the entire trunk, and especial attention is given to the muscles of the abdomen and extremities. In central galvanization the chief aim is to affect the central nervous system; in general faradization the chief aim is to affect the muscular system, although the nervous system, central and peripheral, is affected both directly and reflexly.

Comparing the effects of central galvanization with those of general faradization, we find that both are powerful tonics, and are adapted for conditions of debility, by whatever names they may be known. For some cases, and particularly for cases associated with great muscular debility, general faradization is more effective than central galvanization. On the other hand, in cases where simply exhaustion of the nerve-centres is the leading condition—as hysteria, chorea, and so forth—central galvanization is oftentimes far superior to general faradization.

Central Galvanization Alternated with General Faradization.—Some of the best results that we have yet seen have been secured by combining or by alternating the two methods.

Sometimes, after general faradization has done all that it is capable of, central galvanization, rightly used, helps to lift the patient still higher. In cases where we are not experimenting, and seek only the best good of the patient in the shortest time possible, we use in succession, or alternation, and with changes and modifications, all the principal methods—local galvanization of the brain, of the cervical sympathetic and spine, general faradization and central galvanization. This course is found to be oftentimes justified by the results. The improvement is more positive and more permanent than when a single method is used exclusively.

Some cases we treat one week by general faradization, the next week by central galvanization; sometimes we alternate the methods from day to day.

There are, however, cases not a few, where all forms of faradization and where local galvanization of the nerve-centres irritate rather than benefit, but in which, under the method of central galvanization, there is sure and constant improvement.

Reply to Objections against Galvanization of the Nerve-Centres.—It is proper here to consider briefly some of the objections that have been brought against galvanizing the nerve-centres by the method of central galvanization, or by any form of local galvanization. These objections, which in some instances have come from persons who on other subjects are well informed, are of a threefold character.

1. That the current goes around the nerve-centres, and not through them. This objection is fully met by the experiments recorded in Electro-Physiology. In Electro-Physiology will be found detailed experiments which attempt to prove both *pro* and *con.*

2. That we do not completely understand what the current does when it penetrates the nerve-centres—in other words, the rationale of the effect of electricity on nutrition is not yet an exact science. This objection is just enough, considered as a fact, but considered as an argument it at-

tempts to prove too much. By referring to Electro-Physiology we shall see that there are few, if any remedies, the action of which is as well understood as electricity. We do not exactly and exhaustively know its action on the nerve-centres, neither do we exactly and exhaustively know its action on the peripheral muscles and nerves, and if this objection is to hold good against galvanization of the nerve-centres, it must also hold good against all peripheral galvanization and faradization.

3. That it is dangerous to apply the galvanic current through the head and neck.

Dr. Anstie, who was a very strong friend of electro-therapeutics in general, in his excellent work on neuralgia, speaks of galvanization of the cervical sympathetic as a method to be either avoided or used with very great caution, and, in support of this view, adduces a case in his own practice. The error of Dr. Anstie consists, not in enjoining caution, since this is needed in all electric applications, but in suggesting the idea that galvanization of the cervical sympathetic is a dangerous procedure, likely to produce serious results. Long ago the late Dr. Brown-Séquard, in a foot-note to one of his series of very able papers, spoke as follows:

"Recently, some bold physicians have tried to galvanize the cervical sympathetic nerve. This I did once in 1855 on my eminent friend Prof. Ch. Rouget, to try to relieve him from a most violent headache.

"The effect was all we could desire against the headache; but the galvanic current, acting at the same time on the sympathetic and the vagus (the simultaneous excitation of these two nerves cannot be avoided), produced such a dangerous syncope, that I promised myself that I would never try again to apply galvanism to the cervical sympathetic of man." *

The best reply to objections of this nature, coming from men who are justly distinguished in the departments to which their lives are devoted, is found in the *argumentum ad hominem*.

Dr. Anstie highly recommends hypodermic injections of morphine in neuralgia.

If, now, we should say to him that we knew of a case where an injection of morphine had almost instantly caused most alarming symptoms, and of another case where it had apparently caused death, consequently we had resolved never again to use that method of treatment, he would reply that hypodermic injections had been tested for years at the hands of many of the best physicians of our time; that those who are most familiar with them are usually the most attached to them; and that, when properly administered with the caution that all potent remedial measures demand, and the skill that only experience can give, they need seldom or never do serious harm; and that the infinitely small chance of their doing harm, when thus properly used, is so far overshadowed by the infinite relief

* Archives of Scientific and Practical Medicine, p. 92, No. 1, 1873.

which they unquestionably do afford, as to be hardly worthy of consideration in the practice of those who have made themselves familiar with their administration.

Dr. Brown-Séquard has, among very many other researches, deserved well of the profession for having given an explanation of the action of ergot on unstriped muscular fibre, and for having, on the basis of this explanation, suggested the value of that remedy in congestion of the spinal cord.

If, now, we should say to him that there are cases where, with well-defined symptoms of hyperæmia of the cord, ergot at once aggravates the symptoms, we should but state the truth of our experience. He could reply, however, with perfect justice, that just as there are those in whom a single strawberry will cause most disagreeable symptoms, or those to whom a mouthful of mutton is a mouthful of poison, just so there are those who, whatever their disease may be, cannot bear ergot; but that, when wisely used by those who know what they are about, it is a remedy of vast and various efficacy.

For hypodermic injections of ergot, substitute galvanization of the cervical sympathetic, and our reply is complete. There are those to whom electricity, however administered, is a perfect poison, and who were not born to be treated by this most potent of remedial agents. There are those who can bear it in well-nigh limitless doses.

There are those who can bear it and who are benefited by it, but only when given with delicacy and great caution. Now, it is possible to galvanize the cervical sympathetic in all three classes, except the first, without doing any serious injury, permanent or temporary. Even those who are the most susceptible to electricity, for whom this force can never be beneficial, can yet be treated by the method of central galvanization, with very mild currents and short sittings, and a rheostat of some kind to avoid interrupting the current, without any permanent or temporary injury.

All our most potent remedies are dangerous when used dangerously.

4. That the cases which have been treated by galvanization of the brain have been so carelessly and unscientifically studied, and so recklessly reported, that they have no scientific value. Dr. Cyon, in particular, declares that the observations that are given as proofs of the curative effects of galvanizing the brain are valueless. This statement is unfair. What is true of certain electro-therapeutists is not true of all. The therapeutics of galvanization of the brain have been studied by men who have been trained to the habit of close and discriminating observation; who recognize and bear constantly in mind the enormous complications that beset all therapeutics; who have worked under the gaze of watchful skeptics, and with the everlasting motto, *post hoc ergo propter hoc*, incessantly ringing in their ears; men, too, who have carried conscience into science,

and have reported the results to the world just as they were revealed to them.

It is of very little practical consequence whether these effects are due to the direct passage of the current through the brain or to the reflex action of the current on the brain through the sensory nerves. Reflex action comes in to explain the therapeutic effects of electricity, however and wherever applied. Granting for one moment, what is not true, that mild currents cannot penetrate the brain, this would be no reason whatever for abandoning the electric treatment of the brain so long as experience shows that benefit is derived thereby.

CHAPTER XIII.

STATIC ELECTRICITY.

THIS chapter will be devoted to a practical presentation of those features of this subject most useful to the physician of to-day.

Although the early history of static electricity is very remarkable, showing an experimental research into its nature, physiologic effects, and clinical results which have hardly been surpassed in our own time, and to the reports of which modern investigators are greatly indebted, yet we cannot in this chapter narrate the interesting story of its eighteenth-century development, the gradual evolution of frictional machines into the more powerful induction apparatus of present date, or note the distinguished individual names identified with every step of progress since Guericke's revolving sulphur ball. The chapter on Electro-Physics and other sources may be consulted for information of this character, while we proceed directly to the study of static electricity as we know it to-day and employ it for therapeutic purposes.

Apparatus.—The essential modern apparatus is the Holtz type of induction machine containing not less than six revolving glass plates, twenty-six or twenty-eight inches in diameter, and ranging above this size to eight plates of thirty and thirty-six inches in diameter. We prefer and use this latter size, from which more powerful and better results are undoubtedly obtained.

The Holtz induction machine is dependent for satisfactory operation upon—(1) A means to charge it; (2) a means to revolve it.

The lack of convenient and reliable means to serve these two purposes has long been the main obstacle to the use and popularity of static electricity rather than the commonly stated fact that the apparatus was bulky and expensive. It is obvious that mere considerations of a few cubic inches in the size of a valuable therapeutic appliance, or of a very small addition to its cost, cannot be seriously regarded as outweighing the demonstrated worth of an important curative agent and preventing its employment in progressive medicine.

A small frictional machine of the Wimshurst type has lately been provided as a charger which entirely removes the chief cause of disappointment in the former use of static electricity. This charger will produce a current by direct friction under all conditions of the atmosphere. It may

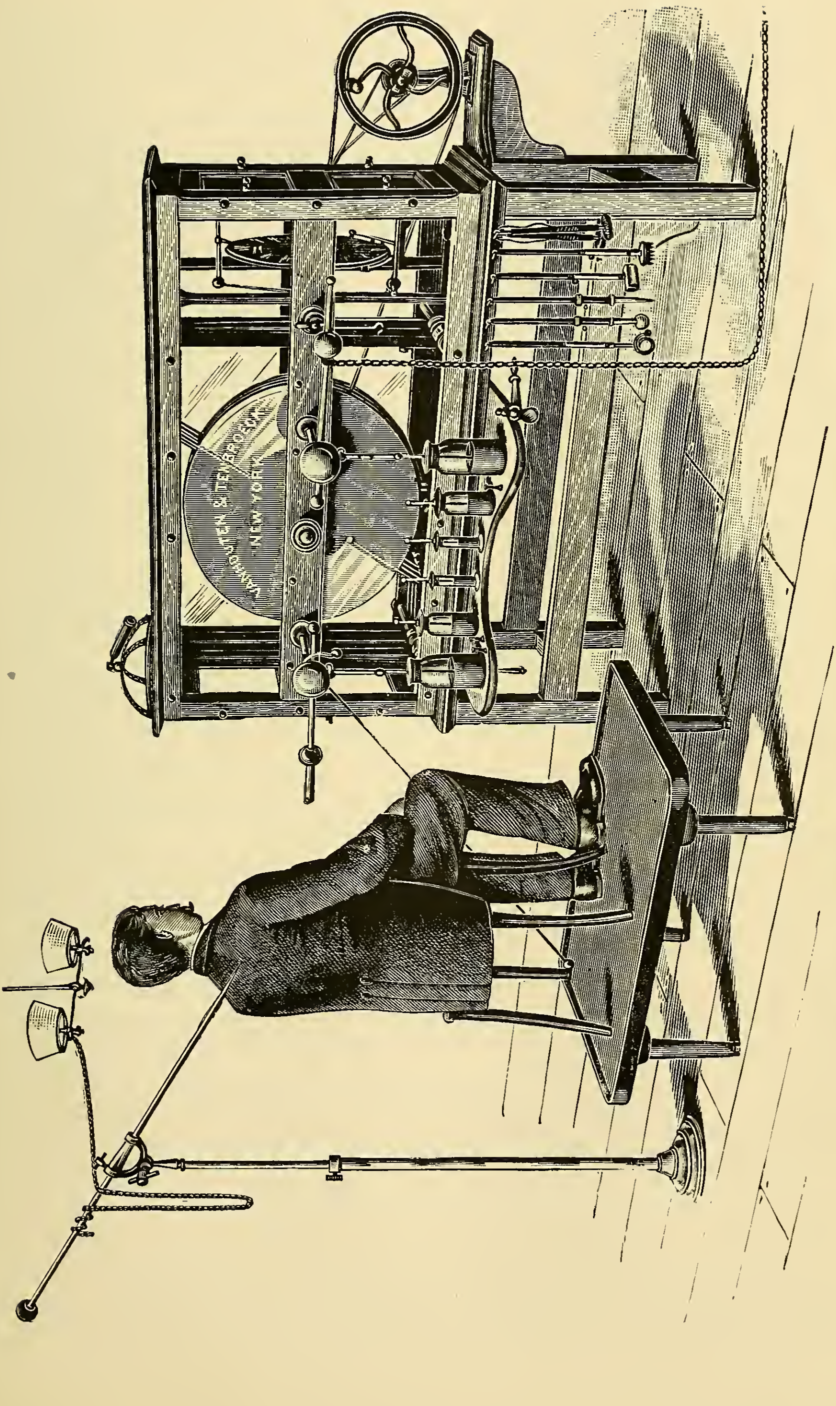

FIG. 113.—Holtz Static Induction Apparatus with Wimshurst Attachment (Van Houten & Tenbroeck).

be constructed inside the case of the Holtz machine, thus increasing its dimensions materially, or it may be obtained in a separate, portable case to be brought into use only when actually needed.

Throughout ten months of the year in this climate a properly cared-for Holtz machine will rarely discharge itself and gives little or no trouble on this account, but inasmuch as it is utterly useless until it is recharged, the importance of a ready means of doing this is equal to the total value of the major apparatus. With the Wimshurst charger at hand we no longer suffer annoyance in this respect.

For means to turn the static machine we may employ an electric motor run by a street current if it is available, or a water motor if facilities for using it exist; or we may get equally good results by hand power, although in this case the necessity of an assistant or the presence in the office of a servant may at times be an objection. Storage batteries are not yet quite satisfactory for operating static machines, and few if any have been so employed previous to this date. Improvements are now anticipated which will probably permit their use under favorable conditions in the early future.

The illustration (Fig. 113) sufficiently represents the mechanic source from which we obtain static electricity of high potential. It is a Holtz induction machine containing a Wimshurst charger. The illustration also shows the operating platform in position with the upright standard holding in position the pointed rod for the application of the static spray. The ball, the roller, and other necessary electrodes are seen hanging at the right of the machine.

A protecting case so constructed as to be as nearly as possible air-tight is of great service in excluding the entrance of dust and moisture from without, which would seriously affect the current. With this machine are furnished several sizes of Leyden jars, an insulating platform, and a set of the peculiar and characteristic electrodes with which applications are made, and which have come down to us with little alteration in type or method of use from the older electricians of the past century. A standard for holding any electrode with which a continuous application is being made is equally essential. It is important that the platform should have rounded corners and substantial glass supports in order that insulation shall be as complete as possible. The matter of groundings, both for the inactive pole of the machine and for certain electrodes, is of prime importance in securing the best results. It is advisable to have two separate metallic conductors to moist earth, although some are in the habit of simply dropping a chain from the machine to the floor in grounding it.

For more than a hundred years and until quite recent times and the introduction of large induction machines, direct metallic connection between the patient and current was the general rule. Modern improvements have led to more wasteful methods of application and probably in this fact we may find an explanation of the difference in clinical results reported by some observers.

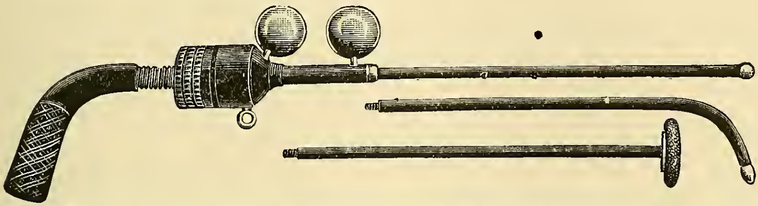

FIG. 114.—Morton's Pistol Electrode, with Attachments for External and Internal Applications.

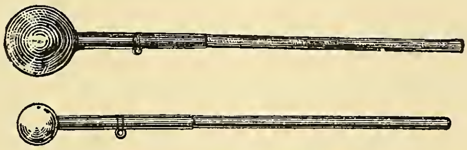

FIG. 115.—Spark Electrodes.

FIG. 116.—Carbon Electrode for Spray Application.

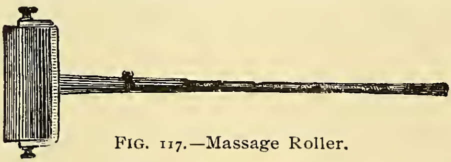

FIG. 117.—Massage Roller.

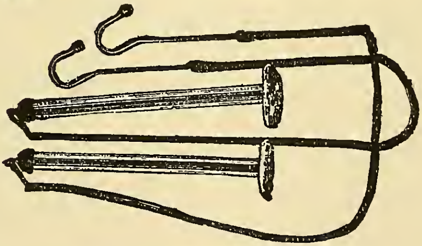

FIG 118.—Handles and Sponges for Leyden Jar Currents.

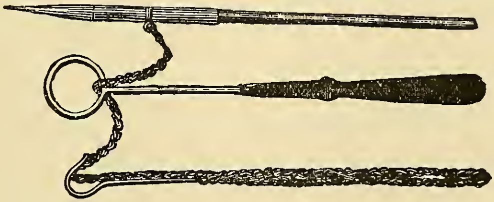

FIG. 119.—Breeze Electrode, Metal Point. Chain-Holder.

The length of spark produced with the largest Leyden jars in the circuit is usually cited as the measure of the power of the machine. This spark should be thick, and exhibit volume as well as length of leap (ten, twelve, or more inches, according to the radius of the plates), but it is not applied to the patient in this form.

Electrodes.—Among the dozen various electrodes furnished by manufacturers of static machines those illustraetd above are most frequently employed. The metal point and ball electrodes are the principal ones, while besides these, operators possessed of original ingenuity will devise such special modifications as their cases call for.

Place in Medicine.—The opposite views expressed at different times by different observers in regard to the value of electricity in medicine have reached their most contradictory extremes in discussing the static form of current. In grouping conflicting views together one very noticeable fact is made clear, viz., that the advocates of static electricity in general speak from abundant personal experience with it, while those who denounce it have usually had little or no experience with it in actual practice. An attempt to fairly establish the verdict of the profession in regard to the recognized merits of this form of current was made a year ago by Dr. S. H. Monell,* of Brooklyn. A presentation was made of the published opinions of thirty different writers. Of these, twenty-two accorded to it a recognition of worth, varying all the way from occasional usefulness to superiority over faradic currents and equal value with galvanism. Eight of the thirty authors expressed unfavorable opinions at one time, but four of them afterward retracted their previous statements and were convinced of its merits by later experience.

The four distinctly prejudicial opinions remaining were shown to be merely the expression of men admittedly uninformed on the subject of static electricity, and whose views therefore could have no serious weight. We cannot perhaps do better in stating our own view than to repeat here the remarks which appear over our signature in the citations alluded to:

"I regard static electricity as a most valuable addition to our armamentarium. No one who expects to meet the demands of all the varying idiosyncrasies of the nervous system can afford to be deficient in the completeness of his electric outfit. Static electrification possesses nutritive and tonic properties of a high order, and in certain conditions one may even succeed in obtaining results after unsuccessful attempts with dynamic electricity.

"Ideas will of course differ as to which of the various manifestations of electricity are the most efficient therapeutically, according to the character and extent of one's experience. After many years of observation and comparative trial, my own judgment is that the dynamic forms of electricity properly utilized (and I emphasize this point because far more care and detail are called for than in the use of static electricity) occupy

* "Practical Chapters on Static Electricity."

a wider field of therapeutic usefulness than the static form; but each form has its special uses and adaptations, and all are indispensable to him who makes much use of electricity in medicine."

It is certain, however, that, quite apart from any theoretical estimate of the medical properties of electricity derived from the Holtz induction apparatus, the usefulness of the machine itself will be what the operator makes it, and no more.

Brilliant clinical results can be anticipated only from the combination of an effective machine and a skilful operator, for they do not follow upon the mere routine administration of this current, which has no recognized electrolytic action. In many respects static electricity is the exact antipodes of galvanism. The contrast is especially marked in their therapeutic relation to resistances.

Character of Current.—Static electricity is a high potential, high frequency form of current. Its disruptive discharges are oscillatory and sinusoidal in character. The direct current from the static machine is not only so deficient in volume as to be devoid of appreciable chemic and electrolytic effects, but is so slender a stream that without accumulating and condensing it under the powerful stress of high insulating resistances we could not employ it successfully in medicine.

The essential accumulation is accomplished by means of the platform placed upon non-conductors (glass legs) which compel the current to saturate the patient before escaping to the earth, and also by means of Leyden jars of various sizes.

In the form of the static charge—the so-called electric bath—this electric manifestation is absolutely unique. No other apparatus enables us to administer a similar application. In furnishing us also the therapeutic breeze and spark the static machine stands alone among the implements in our hands, for although powerful Ruhmkorff coils and alternating current dynamos will produce sparks, they are not adapted to medical usage.

The electro-motive force of the static current far transcends that of the medical faradic coil. Its high potential varies with the conditions under which it is generated, but the maximum obtainable with a large Holtz machine is estimated at thousands and even millions of volts. In respect to frequency, the periodic currents from the static machine are capable of infinite variation. We may so regulate the discharge as to produce but a single interruption per second or minute; or may by mere manipulation of the apparatus or by the interposition of step-up transformers increase this rate to a thousand, a million, or billion or more oscillations per second.

The range of periodicity in the best induction-coil apparatus furnished with rapid and slow interrupters is within about 30,000 per minute.

When we consider the extraordinary modifications we may make at will in the electric product of the static machine it assumes an interest vastly beyond its ordinary recognition in routine practice. Its remarkable inductive effects especially are deserving of careful study, as they take us into a therapeutic field unknown to the observer of galvanic and faradic administrations alone.

Reverse of the Static Charge.—The polarity of the static machine occasionally reverses itself, so that the positive prime conductor becomes negative. This tendency renders it advisable for the operator to always ascertain the polarity of his machine before arranging the connections for treatment. Both the means of detecting the positive pole and of correcting the reversed charge are described by Monell,* substantially as follows: Start the machine into action with the sliding poles in contact. On drawing them apart sufficiently the stream of passing sparks is bright near the positive pole and tinted violet near the negative. Also, if the head of an ordinary match be applied to either pole so as to intercept the spark it will not deflect the stream reaching the negative pole, but by slowly moving the match over the surface of the positive ball from which the spark stream leaps through the air gap, the discharge will be broken, split into fragments, and may be attracted by the operator through a space of the diameter of the electrode. Again, draw the poles apart until the brush discharge is visible at one pole only. This will resemble the classic fox's tail and indicate the positive charge.

To lessen the tendency of the Holtz machine to reverse, the inventor introduced an ingenious diagonal conductor between the upper and lower halves of the apparatus.

The stability of the charge is also still further increased by heavily insulating this bow-rod with vulcanite.

If either situation, with reference to the arrangement of his office and operating groundings, is equally convenient to the physician, his only concern will relate to knowing at which end of the machine he will find the polarity he desires. In some instances, however, especially in rooms of limited size, it is practically important to have the positive charge remain constant in one situation with reference to the groundings and to the convenience of the application to the patient. To accomplish this when a reverse has occurred, discharge the machine, place the sliding poles in proximity, and subject the positive end of the apparatus to a sufficient jar to dislodge the charge and cause it to again shift. The tenacity of the charge will depend on the atmospheric conditions as usual, and this will control the amount of jar required to correct the reverse. At times it is accomplished in a moment; at others it may need considerable patience and persistence, and a variety of methods of producing the dislodgment may be tried before success is attained. One may strike a few sharp taps with a hammer on the outer end of the brass cross-rod sup-

* Medical Record, February 24th, 1894.

porting the upper set of diagonal combs, or tap the prime conductor (first removing the large ball), or very slightly lift the end of the case and drop it to the floor with a jolt. If the charge proves more tenacious, both end-doors of the case may be opened to admit outside atmosphere to the plates, which is promptly effective in hastening the result.

Physiologic Effects.—It is exceedingly difficult to speak comprehensively of the action of static electricity upon and within living tissues, and at the same time appear to avoid exaggeration. If, however, it is borne in mind that different forms of application—in fact, essentially different doses—as well as differing individual idiosyncrasies influence and modify the results, and that in no case will all described effects be witnessed in one person, we shall see that our ground is similar to that of investigators of drug action, who report the physiologic effects of mercury, for example, as a single agent, but administer it in practice in preparations of various activity and strength.

If electricity would do in every case what it is trustworthily reported to do in a very great range of cases, it would indeed be well-nigh a panacea; but we may derive ample encouragement from a fair study of its results to believe that its proportion of failures is not greater than those of drugs deemed most reliable in their action.

Considered as a whole, therefore, we may say that static electricity may increase, diminish, arrest, or otherwise modify or regulate functional processes. It affects secretion, excretion, oxidation, absorption, reflex action, sleep, respiration, circulation, and nutrition. By reason of its high potential, it possesses a power of condensation and accumulation which gives it great diffusiveness and enables it to affect the entire system. In the medical administration of it there are two notable limitations to its effects, to wit, electrolytic decomposition and cauterization; but apart from these its possible influence extends into and runs parallel with the entire range of effects obtained from every other known description of electro-therapeutic currents. In utilizing some of these effects the static machine is more satisfactory than chemic batteries, and in other cases it is less so.

The static spark causes groups of muscles to jump. It is probably the most powerful stimulus to nerve and muscle reaction that can be safely applied, and rapidly imparts tonicity, lightness, buoyancy, and firmness to soft, lax, and enfeebled muscle tissues. Where the thick, heavy spark strikes the surface it causes a vaso-motor constriction, blanching the skin. This soon gives place to a dilatation with redness, and usually a wheal is raised, accompanied by tingling and a sense of heat. Beneath the surface the spark, by its powerful stimulus to muscular contraction, undoubtedly sets up an extensive molecular alteration in the tissues. It thus affects the nutrition of a part, breaks down and disperses exudation material, and gives relief to certain varieties of pain.

Static electrification increases the excretion of urea and lessens the uric acid in the system by promoting oxidation. It increases both appetite and digestion, and also the body weight when the latter has been reduced by impaired nutrition. It lowers the blood-pressure, causes a gentle perspiration to ensue, accompanied by a general sense of well-being. Under the influence of general static electrification, the heart-beats undergo a change, viz., if slower than normal they may be increased ten to twenty beats per minute; or if too rapid they may be reduced in frequency. Without here attempting to account for every possible variation in the effects produced by different applications, our chief interest concerns those general and best-proven effects which relate to nutrition, disordered function, and pain. It promotes the nutrition of every part it excites. It produces marked local and general circulatory effects. It excites to functional action the whole nervous system, fibre, cell, and centre—motor, sensory, special sense, secretory, sympathetic, vaso-motor, etc. It promotes metabolism and tissue changes. On the skin it can be applied as either a counter-irritant or a sedative. It can also vesicate if desired. While its influence upon nutrition may in some cases be very marked, and in chronic cachexias is nearly always decided, yet it appears to make little or no impression upon a person in normal health—affecting in these cases only the local alterations due to its mechanic action at the point applied.

It is profitless to discuss the question as to which of the three familiar forms of electricity possesses the greatest nutritional value. As we have need for them all, and as the particular results of either galvanic, faradic, or static currents will depend somewhat upon the skill of the operator who employs them, a merely academic comparison avails nothing. We all recognize the advantage of a change of remedies at times, and with the aid of three forms of electric currents, each of which supplements and reinforces the other, our results are far more satisfactory than if we relied upon either galvanization or faradization alone.

The electric tension, so to speak, in which the molecular constituents of the body may be maintained during a powerful static charge, is suggested by the action of loose fibres of the patient's clothing and the longer and drier hairs upon his or her head. These all respond to the electric law that opposites attract, and, attracted by the lower potential of negatively-charged objects in the surrounding room, the positively-charged, high potential patient is at every point subjected to a very remarkable influence. A bunch of threads or pieces of cotton twine twenty or more inches long and held by the patient may be caused to stand out in all directions. If a lady's hair be let down and direct metallic connection be made between her and a powerful machine, a rather astonishing display of this peculiar tension will be made.

The keenest interest, however, in the full nutritional capabilities of static electricity is renewed by recent observations of the effects obtained with so-called high frequency, high potential current. We have only to interrupt the usual static current or to further modify it by means of condensers (Leyden jars) or transformers (induction coils), to possess in our own hands the means of repeating those brilliant effects with which Tesla and Thomson astonished the world in 1891, and of producing at will all that is claimed by d'Arsonval, Apostoli, Berlioz, and others for the sinusoidal apparatus employed by Kellogg in this country long before the French observations were made.

It is noteworthy that the methods of general electrification so far incorporated into medical usage involve in all cases a periodic induction current. These are: 1. General faradization (Rockwell). 2. Static induced current (Morton). 3. Sinusoidal application (Kellogg). 4. Vibratory potential alternation (Monell).

Of these methods two are directly administered through the agency of the static machine. All four of them may be if so desired, and even the Tesla oscillator suggests no therapeutic effects which may not be substantially duplicated by some modification of the interrupted static current. In expert hands, therefore, this many-sided machine possesses a unique interest and fills a singular place in medicine.

The Static Breeze.—In this application a local effect is concentrated at any desired point of the patient's body while undergoing general electrification, by utilizing the law that unlike electric potentials attract. The breeze may be applied to the head, spine, or any other portion of the body, and either through the ordinary garments or directly upon the uncovered surface. Both the effects and sensations of the breeze vary with the method of applying it and according to the resistance through which it passes to the tissues. A pointed electrode grounded or connected to the opposite pole of the static machine is brought near to the patient at any situation indicated. Attracted by the opposite potentials in proximity, a brush discharge of electrified particles of air flies in a vigorous current toward the patient, while at the same time a reciprocal discharge from the patient occurs at the site nearest which the conducting electrode is held, thus producing the localized alterations of a highly increased rate of electric change. The observed effects of this application may be sedative or irritating, and modified to various degrees of energy according to the intent and skill of the operator. By fixing the point electrode motionless the local effect may be maintained. By swinging the electrode with suitable undulating waves over the head or spine, or as much of the entire body as may be wished, the effect assumes a more general character upon the nervous system and nutrition. Owing to its simplicity, mildness, and profound and unique effects, the static breeze application deserves very careful study. In any given administration the energy of the breeze partakes of the nature of the patient's potential, a fact which should be remembered, as the current nomenclature indicates the opposite. If the patient is electrified from the low potential prime conductor and a head breeze electrode is connected with the opposite pole of the machine, the passing current of electrified air will be dominated by the low potential of the greater magnet of the two, *i.e.*, the insulated patient.

This, however, is called the positive breeze. Its effects are along the line of sedation. It relieves congestive headaches. It allays nerve perturbation. It is antiphlogistic; is drying to a serous or suppurative discharge; removes the heat and itching from a superficial inflammation, eruption, or burn; induces a restful desire to sleep, and if powerfully concentrated and applied with the requisite degree of skill it relieves a great variety of painful conditions, to some of which a local electrode could not be directly applied.

The aching and swollen mucous tissues from which a number of diseased teeth have just been extracted is, for example, a crucial instance of its power to soothe pain, relieve congestion, and hasten resolution.

If the patient is electrified from the high potential pole the energy of the breeze attracted from the negative (low potential) electrode partakes of the nature of the high potential charge, and is manifestly much more stimulating, and is even irritating when applied through woollen fabrics or upon the hair-covered scalp. It may thus be used as an efficient nutritional stimulant to the scalp or spine, as a counter-irritant to any cutaneous surface, and may be modified in strength from a gentle air current to a strong breeze, and even a decided electric spray in which minute and coarser sparks flying from the point electrode will add a peculiar tonic effect which in the case of cold extremities, deranged circulation, chronic torpor of certain tissues, impaired sensation, myalgias, etc., is exceedingly beneficial and lasting.

When any form of static breeze is applied to the head or about the region of the neck all metal hairpins and ornaments should be laid aside. Corsets seldom require removal. Only by considerable personal experiment with the different sensations produced by the breeze in different concentrations and through different fabrics can the operating physician acquaint himself with the necessary variations in management required to meet each case and avoid the liability of causing a disagreeable effect. So much has been said about the delightful and exhilarating nature of the static breeze that many may be astonished to find that it often requires both tact and expertness to utilize its valuable properties with the maximum of satisfaction and the avoidance of occasional and disagreeable surprises to the patient. In addition to the familiar and simple form of breeze the scope of the connective discharge is amplified by experts in a variety of ways. In certain forms of headache and nervous irritability sedation is admirably effected by the use of two electrodes, one directing a breeze to the cervical spine and one to the forehead. This doubling of the breeze application is still further amplified by completely encircling a zone of the patient's body with a "static cage" of coarse wire netting, within which metallic points or tinsel brushes act as a multiform breeze electrode and produce the effect of an electric shower-bath. Oscillations may be produced by interrupting the current, and the strength is increased by standing the patient on a foot-plate. Operative technique plays an important part in the comfort of this application.

Methods of Administration.—In the administration of static electricity the first step is accomplished by insulating the patient upon the wooden platform supported on glass legs and connected by a metal chain or rod

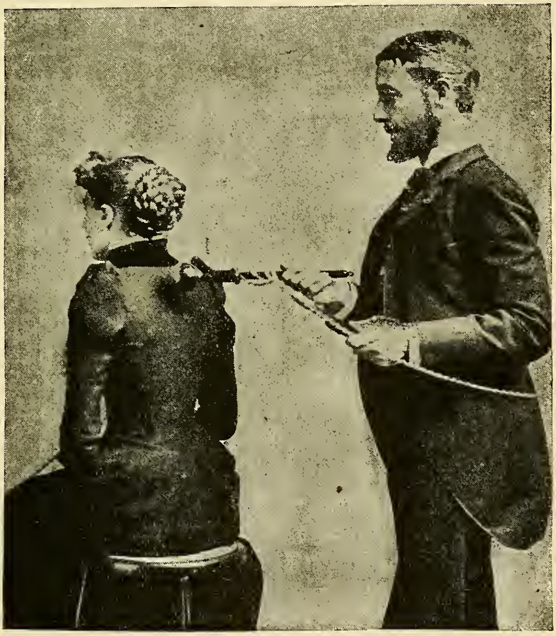

FIG. 120.—Drawing a Spark from the Spine.

to one of the prime conductors of the machine, and connecting the opposite pole to the ground. A general electrification of the patient ensues upon starting the machine into action. This so-called static charge is not only the foundation step to the subsequent application of two other methods for which electro-therapeutic resources contain no substitute or equivalent procedure, viz., the breeze and spark, but it constitutes in itself a very effective and useful method of treatment. Fig. 120 illustrates a patient seated upon the insulating stool—in a condition of insulation—while the operator is in the act of drawing a spark from the spine. The high potential (positive) pole is usually selected for general electrification.

The low potential (negative) pole is theoretically indicated as a sedative in states of hyper-excitability; while the normal electric state in health being positive, we attempt to restore this state in our patient by submitting him to the influence of the positive charge, which is held by some authors to be a stimulating tonic. In either case the process of electrification is nearly a silent one. The patient is just conscious of a rather agreeable influence, and ordinarily the feeling of restful composure which ensues in from ten to twenty minutes is the most obvious effect of the application. A very gentle diaphoresis may result, most pronounced in neurasthenic cases—and the well-known effect upon the hair is witnessed. To secure the best effects of this electro-atmospheric bath the fullest powers of the Holtz machine should be brought into action. Direct metallic conduction should be made, either by placing the patient's feet upon a plate or holding the connecting rod in one or both hands. The habit of merely resting the end of the rod upon the surface of the platform wastes a large proportion of the current and diminishes the supply to the patient. It is no doubt owing to the fact that success here depends upon a powerful and not upon a feeble electro-static influence that opinions differ as to the value of simple insulation. In our experience it is valuable and beneficial in exact proportion to the patient's relative need for it. It is tonic and refreshing in its action. The extremely negative person, if we may use the word, who is anæmic, neurasthenic, emaciated, enfeebled perhaps by a recent acute illness, extremely susceptible to changes of weather, with deficient animal heat and poverty of nutrition, will in many ca es be improved by the positive charge as by a miracle. The effects are less marked as we approach a normal state of health, and the average healthy person will be unable to observe any particular secondary action upon the system from the simple static bath. In regard to the oft-disputed question as to the sedative influence of the negative pole and the stimulating influence of the positive pole, our own conclusion is that some of the differences reported are due chiefly to the state of the patient, and that in a series of ten differing cases—differing in neurotic manifestations—as great variations in effect would be reported from the positive pole alone as are held to exist between the two poles. One is a low potential energy, the other is a high potential; but both are different from the assumed potential of the body, which is nearly that of the earth, and therefore are alterative and potentially beneficial, and whether either is more or less sedative than the other depends on the patient, and duration of treatment rather than the polarity. Both are tonic in their gentle and agreeable influence, and in no case known to us has either pole ever proved to be in any degree injurious.

The opposite view that negative electrification is a depressant is largely traditional in its origin and is not borne out by clinical experience. Both theoretically, however, because of its greater difference of potential, and practically because of its more definite subjective effects, we usually employ the positive pole alone in most cases of simple electrification. It seems to be by no means stimulating in the sense of exciting irritability, but on the contrary often proves to be one of the best sedatives in our hands in cases of insomnia, nervous excitement, fatigue, neurasthenia, etc. It is particularly indicated also in the malarial cachexia, and usefully supplements other remedies in a great variety of cases which are too numerous to be referred to in detail.

As there is no age or condition of debility in which general electrification causes any inconvenience to the patient, and as it requires no special preparation or removal of clothing, it is on these accounts adapted to very general use for its tonic and nutritional influence, and in certain cases can be employed when no other electric application can be satisfactorily made for the same purpose.

The Static Spark.—When an insulated body is electrified from either prime conductor of the Holtz machine, and an electrode terminating in a metal ball instead of point is connected by a chain to a grounding or to the opposite pole (or to both as may be advisable), and brought sufficiently near the attracting body of the patient, the limiting tension of the dielectric—the air gap between the "unlike electricities"—is broken down disruptively instead of connectively and a visible spark passes from the lesser to the greater electrified body. This spark strikes a blow proportioned to its size, electro-motive force and density, and sets up a local alterative perturbation in the tissues at the site of the blow, and instantaneously produces the general systemic effect of a complete interruption and discharge of the current from the electrified body. The potential of the patient is thus reduced to zero with every spark, rising instantly again to the high potential of the renewed electrification which at once succeeds each discharge while the machine is kept in action. The therapeutic impression upon the patient is therefore twofold, and the spark is a powerful as well as unique remedial agent in the hands of one who employs it judiciously, and who with equal skill and judgment lets it alone when it is not indicated. The beneficial use of static sparks calls for some degree of tactful management on the part of the physician. The size, density, and electro-motive force of the sparks applied to the patient may be graduated and varied in effect from the merest surface shower of rubefacient frictions to great percussive blows which throw whole groups of muscles into powerful contraction and mark their impact by temporary wheals upon the skin as large as silver dimes. The powerful percussive spark, however, is not necessarily more painful or disagreeable than the milder one; nor is any static spark liable to do injury to the most delicate fabric through which it passes in the treatment of a patient.

The thickness of the spark is partly dependent on the capacity of the ball electrode. Two sizes are furnished with static accessories. The larger one will give off the heaviest spark when desired. When this electrode is rubbed rapidly over the surface of a part covered by ordinary wearing apparel a rapid succession of minute short sparks passes through the garments, producing a revulsive stimulating effect upon the skin and muscles and a reflex impression upon the nervous system. The same effect is produced on uncovered surfaces by wrapping the electrode in a cover of woollen cloth. These short, fine, calorific frictional sparks constitute a distinct method of application especially valuable in myalgias and as a cutaneous stimulant.

The long, thick, percussive spark in contrast to the above is applied to the patient through the high resistance of several inches of intervening air which the overstrain of tension breaks down. In administration, this form of spark should be clean, thick, distinct, straight, and single, and never delivered in a fusilade. If groundings, insulation, conduction, and machine are properly related to the patient and the ball electrode, there will seldom be any complaint. If the spark, though long, is thin, flies at random splits into fine particles, and stings annoyingly despite care, the cause is to be sought in some part of the circuit where the current finds an error in the connections. Too great caution cannot be exercised in knowing in advance that every part of the apparatus is in correct order before electrifying a patient. It is also well to note that different parts of the body vary much in their susceptibility to electric influences, and the operator may wisely subject his own person to the different applications of both breeze and spark until he is thoroughly familiar with each. By this means he will be enabled to avoid the few particularly sensitive regions, bony prominences, etc., which it is best to exclude from energetic local irritation.

The Massage Roller Electrode is employed in either of two ways. The first involves insulation of the patient with the electrode connected by a chain to the opposite pole of the machine. The two sliding poles of the apparatus are then brought near enough to each other to give an interrupted current of the desired strength, while the roller is passed over arms, spine, abdomen, or any portion of the body to be treated. Modifications of current strength are made by increasing or diminishing the distance between the sliding rods, by varying the speed of the revolving plates, and by moving the electrode more slowly or rapidly over the surface to which it is applied.

In the second method the patient need not be insulated, but can be treated from the positive pole alone, the negative being grounded.

The term massage is partly expressive of the nature of this application, but falls short of indicating its complete efficiency. It is really a modification of the static spark, both in its frictional and percussive forms, and is especially useful in muscular rheumatism, lumbago, sciatica, and various neuro-muscular conditions requiring tonic and sedative treatment. As a passive exercise it can be made as stimulating as desired by withdrawing the poles sufficiently apart.

Leyden Jar Current Applications.—Three siezs of jars—small, medium and large—are usually included in the equipment of a Holtz machine. By connecting a pair of any size to the prime conductors of the machine and connecting the outer coatings of these jars together by means of the metal rod designed for this purpose, a condensation of current is effected, which increases the electrification of the patient and augments the force of it in proportion to the capacity of the jars. In humid weather, when a high potential cannot ordinarily be maintained, the assistance of Leyden jar condensers is therefore valuable. This is their simplest use.

By another method they are the means of our obtaining from the static machine nerve and muscle reactions similar to those produced by the induction coil currents in common medical use under the general term of faradic electricity. A pair of jars being connected to the prime conductors of the static machine, there may be attached to the outer coatings of these jars by ordinary conducting cords any form of moistened or bare metal electrodes employed in faradization. As faradic currents are conformable to the fineness, length, and windings of the coil and rate of interruption, so the static induced current is quantitatively regulated by the size of the jar, and in action by the rate of interruption. This rate is determined by the speed of the revolving plates of the machine and by the distance between the sliding poles. A single spark may be allowed to pass, or the frequency may follow all the variability of faradic vibrators, and even go infinitely beyond them.

It is estimated by physicists that each spark is composed of an immense group of subdivisions, representing a total aggregate of millions of oscillations per second; and it is this fact, together with the enormous voltage of the current, which supports the superior claims that have long been made for its power to relieve pain, contract muscles, etc.

Properly adjusted, the static machine produces a smooth and agreeable current, resembling in its general characteristics the currents now obtained from high-tension induction coils; and while it may be fairly asserted that for working purposes the Holtz machine provides the advantages of both systems, yet in practice the physician who has the best of modern coils at his command will rarely require to use a Leyden jar substitute. The static induced application was described by Morton of our own country as early as 1881, and independently and about the same time by Bartholow, and subsequently by writers in both England and France, where the use of static machines was being revived in advance of their improvement in America. While never in very general use, and sharing the drawbacks inseparable from the nature of its source, yet in therapeutic efficiency the value of this form of static electricity cannot be doubted.

It is chiefly because we have other means less costly, less cumbersome, more easily operated, and absolutely independent of atmospheric heat and moisture, that we neglect a method which, had we no substitute, would command much greater recognition.

A detailed description of either indications for static induced currents or methods of applying them is quite unnecessary, as physicians are already familiar with faradization.

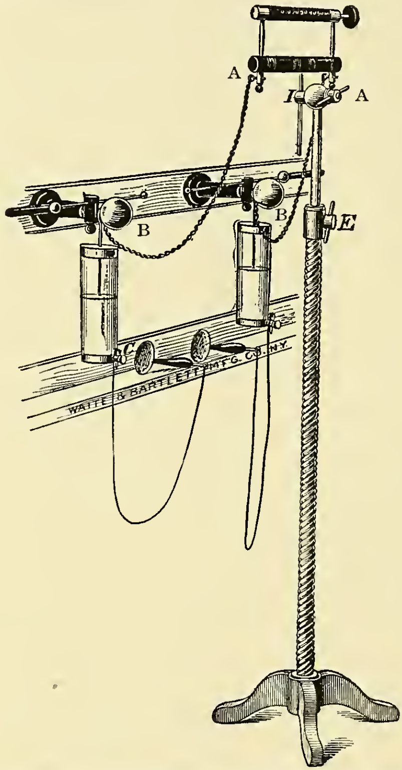

FIG. 121.—Ranney's Static Current Controller (Waite & Bartlett).

The third manner of utilizing the jar condensers furnishes the remarkable high potential, high-frequency current lately exploited by a number of writers both in this country and abroad. Apostoli, d'Arsonval, Berlioz, and other have published accurate accounts of the effects of these currents on nutrition, circulation, and motor and sensory nerves. A primary coil is made of a few turns of very coarse copper wire, over which is the finer secondary coil, insulated from the primary by either an oil-bath or several thicknesses of heavy paper soaked in oil. This step-up transformer is connected with the Leyden jars and to the electrodes. Sedative effects in acute inflammations are obtained, and relief from neuralgias and rheumatic pains, and in symptomatic neuroses, more speedily than from the usual induced currents. Nutritional effects are also said to be more marked.

Fig. 121 represents a convenient device for controlling the static induced current. The connections with the static machine are made between the points *A A* of the device and the poles *B B* of the machine. The electrodes are attached by binding posts to the Leyden jars *C C*, and the current is controlled, being increased and decreased without shock by the movable disk *F*.

Vibratory Potential Alternation.—This method of general administration originated with Monell and was described by him in 1893. In its simplest form it is an electrification with an oscillatory instead of constant static charge.

Without doubt it has a more energetic effect upon nutritive processes and the general nervous system than the usual uninterrupted insulation, but its efficacy depends very largely upon proper conditions of machine adjustment, and in incompetent hands it will not give invariable satisfaction. Some additional interest, however, is at present imparted to such an oscillatory application from the remarkable experiments of Tesla with his so-called oscillator.

Besides a general vibratory treatment, this method is employed in various local applications.

In its local application, however, this method can hardly be called new in principle, since it merely adopts the idea mentioned in the earlier editions of this work, of breaking the current by a spark elsewhere than on the patient, a device which dates back to nearly the middle of the last century. The patient is insulated and direct metallic connection made with the positive pole of the Holtz machine, to secure the full power of the current. The negative pole is connected to the ground and to a breeze electrode, which is used to attract the charge from the patient at a distance of about thirty inches—usually above the head. A large ball electrode is then fixed upon a standard connected with an entirely separate grounding, and brought near the end ball of the brass rod resting on the positive pole. The machine must be brought into vigorous action and the most powerful oscillations developed. If properly done there is no local sensation produced, but the patient is wrapped in a vibrating atmosphere, of which he is agreeably conscious. The effect is restful and soothing, and much more demonstrably so than ordinary electrification.

Therapeutics.—So dependent are therapeutic results upon technical conditions controlling the administration of static electricity, that no author can state an opinion of its value in treatment without finding some to disagree with him. If all who claim successes with this agent were placed in line, while all who report failures were placed in another, an expert could probably pass in turn from one machine to the other, and point out the reason for such opposite results. Certain it is that many disappointments could be avoided if a more careful study of the machine itself, its care and operation, was made by those who employ it without satisfaction.

From franklinic electricity in the form of sparks, sprays, and general franklinization, tonic and sedative effects of a very interesting and positive nature can be obtained, either by insulation, by sparks, or the use of the roller. Speaking from a considerable experience with this form of electricity, we should say that, while its constitutional tonic effects are not superior and perhaps unequal to those that follow general faradization, when this method is carried out properly, with due attention to detail, yet as an adjunct or supplement it is invaluable. It is one of the familiar things in medicine that a remedy which at first acts well may, after a time, prove inefficacious, rendering it necessary to resort to some other remedy of the same class. This is true in regard to the dynamic and static forms of electricity. Occasionally cases of nervous exhaustion as well as other forms of disease, after improving to a certain point under the influence of the galvanic or faradic current, hang fire, as it were; but by submitting the patient to the action of franklinization a new impulse seems to be given. In this way, one treatment supplementing and reinforcing the others, results are obtained far more satisfactory than could possibly follow the exclusive use of general or localized faradization, central galvanization, or franklinization. Pain is sometimes relieved by franklinization after both galvanism and faradism have failed, but this is not the rule. The pain of muscular rheumatism, however, is relieved by this method sooner and more effectually than by the others. For this purpose, the treatment by the roller, which exercises a generally stimulating effect over a broad surface, is superior to the treatment by sparks.

In the various forms of true neuralgia, franklinism is not comparable in power to galvanism. The pain that the former is frequently so successful in subduing is generally of a chronic character, confined to no special nerve-trunks, dull and aching in character, and with no tenderness on pressure. In these cases we have long known that the faradic was superior to the galvani: current, but more recent experience has convinced us that franklinization is more efficacious than either. In the enlarged joints of subacute and chronic rheumatism, and to excite the process of absorption in chronic synovitis, the treatment by sparks is frequently more efficacious than either faradization or galvanization. In old contractions and in cutaneous anæsthesia, franklinization frequently possesses advantages over the others.

In locomotor ataxia, and in systemic diseases of the spinal cord in general, it is rendered probable by a number of suggestive cases that much more can be accomplished by the use of franklinic than by dynamic electricity.

As an alleviator of pain the static induction current possesses qualities of a high order. It is inferior to the galvanic current in this respect, and yet it does relieve as does the faradic in some cases, when the galvanic has failed. Further experience with the static induced, however, convinces us that it will, on the whole, do more for the relief of pain than the faradic. It is well known that the induced currents of tension are far more efficacious in relieving pelvic pain than currents of quantity, and the static induction current is a current of but little quantity but enormous tension.

When we consider that its voltage runs up into the thousands, it is no difficult matter to accord to it, despite its lack of quantity, special physiologic and therapeutic properties. In the immense rapidity of its interruptions and alternations also the franklinic interrupted current is unique. While the average induction coil gives but a few hundred vibration per second, it is claimed by physicists that the oscillations of each spark of the static current amount to many millions per second, and that these sparks follow each other at the rate of two hundred per second.

The superiority, then, of the static induced current over the faradic in relieving pain is undoubtedly to be ascribed, first, to its superior tension; second, to the inconceivable rapidity of each spark oscillation, amounting to many millions per second.

For the relief of the dull aching pain associated with so many of the occupation neuroses, and especially with writer's cramp, we have found the interrupted franklinic current to be especially efficacious, and in any form of peripheral and muscular paralysis, its more energetic stimulus to nerve and muscle renders it a more efficient remedy than the ordinary faradic current.

In subacute and chronic affections of the joints, in lumbago and muscular rheumatism generally, and in some cases of sciatica, this current is invariably superior to the faradic, and as a rule to the galvanic also. In insomnia the static bath is invaluable. In electro-diagnosis franklinic electricity has about the same range of usefulness as the faradic current, but has no power to indicate those qualitative changes which are so important as indicating structural degeneration.

CHAPTER XIV.

ELECTRIC BATHS.

A METHOD of employing electricity that has long been popular among the laity, and is now being more or less used and recommended by the profession, is the electric bath. The methods of giving electric baths are various. The requisites are a bathing tub of some form, partly filled with water, contrivances for sending the current—either faradic or galvanic—through the water in which the patient is immersed. An electric bath can be extemporized in any ordinary bath-tub. The patient may rest his feet on one pole in the water and hold the other pole in his hand. In that position the body of the patient becomes part of one or the other pole, and the current flows through him from one pole to the other, just as it would if there were no water in the bath; or at most the only effect of the water is to thoroughly saturate the part of the body in contact with the pole in the bath. This method is, of course, exceedingly crude, and can scarcely have any conceivable advantage over a similar position of the poles outside of the bath, and yet it has been not a little used.

A form of electric bath often used is the following: The tub is of the ordinary shape, but the metallic connections are so made that the current cannot avoid passing through the body of the patient. One pole—a broad copper plate—is at one end of the tub, constituting a part of its lining surface, and the other pole—also a broad metallic plate—is placed at the other end. Both plates are under the water. At the head of the tub a board is placed, at a little distance from the pole. This board has in it a slit of moderate size. Against this slit rests the back of the patient, while his feet may or may not press against the copper plate at the other end of the tub. By this arrangement the current can be directed through the back of the patient, and from the back through the body and lower limbs. Indeed, the back of the patient fits so closely and snugly into the slit of the wooden rest that the current, if it pass at all, must go through the body.

In regard to the electro-conductibility of the body as compared with water, we have already spoken. The human body is composed mostly of water, holding in solution various salts; it, therefore, conducts better than water of the same temperature; and on account of this superior conductivity of the living human tissue a considerable portion of electricity must go through the body whenever it lies in a bath, even though it does not touch either pole. That the body conducts better than the water is proved by this experiment, which we have often made. Place both hands, at some distance apart, in a bath through which a current of considerable strength is running, and a sensation will be distinctly felt in them. Bring the hands, still immersed, very close to each other, and the sensation will be much diminished. When the hands are far apart a considerable portion of the current passes through the body from one hand to the other. It prefers this much longer and roundabout road to the direct path through the water.

This rule, it is claimed, does not apply to the galvanic current, the tension of which is so slight as compared with the faradic. According to Stevenson, notwithstanding the fact that the resistance of the epidermis becomes so greatly reduced by the action of the warm water, only about one-sixth of the current passes through the patient.

A somewhat different form of electric bath is where on the sides of the tub and near the bottom are a number of electrodes connected with the battery. These electrodes are so arranged that the current can be sent through any one or all of them, and thus be localized on the part that specially needs treatment. In using the faradic current it should be distinctly but not painfully felt—while our guide in the use of the galvanic current with its far greater quantity and slighter tension should always be the milliammeter.

The cataphoric action of the current may be utilized in taking mineral baths, by a very simple method. The anode is simply placed in the bath in which a portion of the body is immersed, thereby making it (the water) the anode. The cathode is applied to any portion of the body not immersed, and in this way that portion of the body in the water becomes subject to the anodal diffusion of the mineral agent held in solution.

The study of the comparative practical advantages of these different forms of baths is of course beset by many complications.

Effects of the Electric Bath.—In regard to the therapeutic effects of the electric bath, we have these remarks to offer:

1. The stimulating, sedative, and tonic effects of electricity are obtained more or less by all forms of electric baths; not only those where the current is localized in some part of the body, but those where it is generally diffused without regard to localization and without regard to current direction, exert, there is no question, more or less the special and distinctive physiologic and therapeutic effects of electricity. Those forms of baths that admit of localization of the current seem to us to be far more scientific and rational than those that do not admit of such localization, but all forms are capable of affecting the system, for electricity cannot pass through the body without doing more or less good or evil.

2. The question whether electricity, administered in any of the forms of baths yet devised, has any therapeutic advantage over the ordinary methods of using electricity—as localized faradization and galvanization,

general faradization and central galvanization—has not yet been established. Even if it should be proved that in certain diseases or certain conditions the electric baths are slightly superior to ordinary electrization, the further question would still arise whether this advantage is sufficient to compensate for the longer time and greater labor and inconvenience of the baths. The question is one of exceeding complexity—for the therapeutic effect of the water is combined with the therapeutic effect of the electricity, and to eliminate the one or the other is no easy task. Enthusiastic advocates of the baths sometimes make the same mistakes as the advocates of franklinization, or the use of statical electricity, of assuming that the results which they undeniably obtain, and which are sometimes most satisfactory, could not just as well have been obtained by a proper use of electricity in some of the ordinary methods.

It is claimed that the baths will be borne by temperaments that will not bear ordinary electricity. This claim may possibly be just, and yet the difficulty of demonstrating it is very great; for those who take the baths and are benefited by them may most likely have been improperly treated by the other methods, and thus fall into the delusion that the baths are *per se* more bearable than ordinary electrization.

The true and only way to determine this question is for those who are masters in electrology to try the baths, side by side with their other methods of using electricity; just as they try the two currents and the different methods of using them on the same patients and on different patients, and in a wide variety of diseases. Observations of this kind, to be of real value, must be not only numerous, but extended over a long period.

The question whether substances can be introduced into the body or removed from it by electricity will be discussed in the section on electro-surgery.

General Rules for Giving Electric Baths.—In the use of electric baths we should be guided by some of the same general principles that guide us in the use of electricity by other methods. The temperament of the patient should be studied, and in the length and strength of the baths and in the frequency with which they are given we should be directed by the peculiarities of each case.

It is not well to take an electric bath just after a full meal, nor is it usually well to take exhausting exercise immediately after a bath, especially for the delicate and nervous. The temperature of the water should be about that of the body, and may range between 95° and 105° Fahrenheit. The patient may remain in the water from five to twenty-five minutes. There appears to be no danger of catching cold after taking an electric bath, even when the water is quite warm. One effect of the electricity would appear to be to give tone to the cutaneous vessels, so that there is less liability to take cold than after a simple warm bath.

CHAPTER XV.

BIPOLAR FARADIZATION.

When Duchenne first called the attention of the profession to his method of localized electrization, it will be remembered that he practically excluded the galvanic current from consideration and confined his experiments almost entirely to the faradic. Remak, on the contrary, and many of his followers, advocated the galvanic current mainly, and for a time a fierce and unreasonable controversy was carried on between the two. In the light of our present knowledge of the different forms of electricity, it would appear little less than childish to champion one form to the exclusion of the others, since there are few diseases for which electricity is indicated where either current might not, under varying conditions, prove of service, and few methods of application where both currents may not be utilized. There is one method, however—the bipolar—which seems to be a special field for the faradic current.

By bipolar faradization is meant the localization of the faradic current by means of a single electrode, and the method is confined for the most part to internal treatment, *i.e.*, to the treatment of the vagina, the uterus, the rectum, and the bladder. In order, however, to any satisfactory appreciation of this subject, it will be necessary to consider a number of facts in regard to the physical and physiologic action of the induction coils, some of which appear to be a veritable *terra incognita*, even to those who make much use of electricity in medicine. It seems hardly necessary to state the simple fact that most induction apparatuses are composed of two distinct and separate coils, one of which, called the primary, is made of thick and comparatively short wire, while the other and outer coil consists of wire that is thin and very long. Every possessor of a faradic battery appreciates also that there is a great difference in the character of the current proceeding from these coils. From the primary coil, as the electrodes are held in the hand, or placed on any portion of the external surface of the body, the current seems comparatively mild and inefficient, while the current from the secondary coil acts with far greater vigor. It not only more vigorously contracts muscle, but excites the cutaneous sensibility more acutely and the retina more vividly than the current from the primary coil. Apply, however, this current (primary coil) directly to the bladder, the rectum, the vagina, and especially to the involuntary muscular fibres of the uterus, and a very remarkable and interesting change is observed. It will be found that the current from the first helix acts with astonishing and most unexpected vigor on both sensory and motor parts. We are accustomed to say that the long thin wire yields a current of tension, and the short thick wire a current of quantity, and the more vigorous action of the second helix, when application is made externally, is commonly attributed to its superior tension; but the immediate and astounding change in the physiologic effects of the two currents when applied directly to the internal organs of the body cannot be altogether explained in this way. Studying the phenomena of induction as produced by the initial voltaic current alone, without the intervention of magnetic force, Duchenne long ago claimed to have proved that the difference in the length and thickness of the wires of the two helices did not alone explain the different action of the two currents on the sensibility.*

The old claim that the currents have elective properties has no solid basis of fact. The reciprocal relations between the nervous system and the action of electricity are by no means clearly understood, and the interesting fact that in external local faradization the current from the long thin wire is the most effective, both as to objective and subjective symptoms, while in internal local faradization the current from the short thick wire acts most vigorously, can only be explained by difference in current strength according to the law of Ohm.

If instead of using the unipolar method—one pole internally and the other externally—we use a bipolar electrode, and in this way treat the vagina, the uterus, or the rectum, the current from the first helix will act with greatly increased vigor, an increase that does not seem to be altogether accounted for by the decreased resistance that is necessarily offered.

Although around the primary coil of an ordinary induction apparatus extra and distinct coils of finer wire up to the number of nine can be wound, the current from each successive coil becomes weaker and weaker, and experience has shown that for all practical purposes there is need for but two helices, or at most three, that yield the primary and secondary induced currents. This apparatus we term the separate coil apparatus, to distinguish it from another combination of helices, termed the continuous coil, and it is the current from these two distinct coils of the separate-coil apparatus to which reference is usually made in the consideration of bipolar faradization. Reference is here made, however, to bipolar faradization in connection only with the continuous coil helix, the efficiency of which over the other form is very great. While in the ordinary separate-coil machine with which Duchenne carried on his original series of experiments, and with which Apostoli and others practise the bipolar

* "Localized Electrization," p. 28.

method, we are limited to two or three currents—the primary induced and the secondary pure induced—we obtain from the continuous apparatus many distinct manifestations of the induction current, four of which at least differ so widely in their physical, physiologic, and therapeutic properties as to render it a matter of the utmost importance that we appreciate the fact that these currents cannot be applied indifferently in practice.*

Indeed, let one become but once convinced by personal experiment of the striking difference in the action of these four qualities of current on nerve and muscle, and he will hardly need the demonstration of clinical experience to convince him of their different therapeutic properties. The current from the primary, or first induction coil of the continuous-coil apparatus corresponds very closely with the current from the primary coil of the separate or double-coil apparatus. The wire is short and thick, offering very little resistance to the passage of electricity, and so gives forth a current of little tension but large quantity, so called. When applied externally its appreciable influence is very slight. Its tension is so low that it overcomes with exceeding difficulty the resistance of the skin that must be encountered in all external applications. Its reflex as well as direct influence is therefore very slight, and it only moderately excites cutaneous sensibility.

It acts with considerable chemic power, readily burning steel or iron, as manifested by the bright deflagrating spark given forth. It will electroplate and electrolyze to a degree not attainable with the other induction coils either alone or in combination. The important practical point, however, in connection with this current is the extraordinary increase in energy that is manifested when application is made to parts within the body. When applied to the rectum, the vagina, or the uterus, not only are the contractions pronounced, by a strength of current insufficient to produce any observable effect when applied externally, but may easily be made exceedingly painful. It may be here remarked that the testes also are far more acutely sensitive to this current than to the currents of pure induction.

Far more severe in its influence, however, is the second current of the series—that proceeding from the primary and second coils of the combination. Externally applied it is comparatively weak, although far stronger than the other; but when applied by the bipolar method to the uterus or vagina, its extraordinary action on motor and sensory parts will hardly be credited without actual demonstration of the fact. It is the easiest thing in the world to demonstrate this fact unwittingly, to the injury of the patient and to the operator's mortification. This is what may very readily occur: An intra-vaginal or intra-uterine bipolar application is being made with the current of tension. The patient complains of an uncomfortable sensation, which may or may not be due to the action of the current, and

* For a more minute description of the separate and continuous coils see page 267.

you shift the slide so as to exchange the current of great for one of lesser tension, which, according to all the experiences of external application, is infinitely weaker. Instantly a shock is occasioned, associated with the acutest pain and the most rigid contractions, that astonishes yourself and terrifies your patient, a mishap which I have known in more than one instance to excite neuralgia and other severe nervous symptoms of a distressing and more or less permanent character.

The advantages of these first two currents of the series over the last two, presently to be described, lies almost wholly in the effects of their internal application, and especially by the bipolar method. Both currents, and especially the current from the combination of the primary and secondary induction coils, act as powerful muscular tonics when applied internally, and are capable of exciting contractions of the involuntary muscular fibres of the uterus of every degree of severity. For this reason it is invaluable in cases of post-partum hemorrhage, and must, it seems to me, prove far superior to ergot for its suppression, since it acts instantaneously, and with a force just sufficient to accomplish the object desired.

In the ordinary form of subinvolution the current from the primary and second induction coil is invaluable. Bipolar intra-uterine applications persistently repeated, and with a strength no greater than can be readily borne by the patient, will afford results so gratifying that no one who has once had experience in the method will wish to treat a case of subinvolution without its aid. In regard to the action of the primary induction coil, in its external application, I have, I am confident, observed certain effects worthy of citation.

Some cases of hyperæsthesia of the scalp and face, and not a few cases of pain of a true neuralgic type and superficial in character, are more readily relieved by this current than by any proceeding from the pure induction coils unassociated with the battery influence.

It is a difficult thing to explain many of the phenomena of electro-physics. We can state them and utilize them, and so render them of immense service in the arts and sciences. Many of the phenomena of electricity as related to physiology are equally unexplainable, but none the less do we utilize them in therapeutics. Why the current from the primary induction coil should manifest a superiority as stated above, it is impossible to say without we ascribe it to that combination of the battery and inductive influence which it possesses in such perfection. The third current of the series—that proceeding from the primary and the second and third induction coils—is of unique quality so far as relates to its effects when applied externally. Like the primary coil it will electroplate, but unlike it, it will not burn steel or iron. The peculiarity of this combination of the coils is that the maximum of power to contract the muscular tissue when the application is made through the medium of the skin is here obtained. Each additional coil that is now attached simply gives a decreasing contractile power, providing the initial electro-motive force remains the same. Add, however, voltage in proportion, and notwithstanding the increased length of coil the power of the current to overcome resistance greatly increases. This current, possessing less quantity, but far greater tension than the two preceding already considered, exerts by no means the same influence over the contractions and sensibility of the vagina, uterus, rectum, or bladder; but its energy of action in this direction is greatly superior to the fourth current of the series next to be described. To emphasize the advantages in bipolar faradization of this combination of helices over the separate form, mark the distinct and varied effects obtained from the first named. The current from the primary coil, although very weak when applied externally, exerts very positive effects upon both the sensory and motor nerves when applied internally. From the primary and second induction coil we obtain a current the effects of which are tenfold greater, and the utmost caution is called for in its application. Adding the third induction coil, the application still being internal, the sensory and motor effects are yet marked, although far less severe than the current from the preceding coils, but greatly in excess of the fourth and last current of the series. This current, for the production of which all four coils are necessary, is in many respects the most important, and has a range of usefulness wider than the others. Its action is pre-eminently tonic and sedative.

The currents from the two preceding combinations of coils are exceedingly harsh, and so keen and cutting in character as to be absolutely painful if carelessly administered. This current, on the contrary, is always agreeable, or at least not painful, even when administered to the point of endurance.

Therefore in the operation of general faradization, when we desire to obtain the best constitutional tonic effects that electricity is capable of giving, we resort to this combination of the coils. While we cannot satisfactorily explain all the complex action of electricity on the tissues as it influences animal nutrition, the same may be said of the action of almost every other remedy. Who can explain why arsenic feeds the nervous system, why quinine breaks an attack of chills and fever, or how opium produces sleep and relieves pain, and who has entered into the mysteries of anæsthesia? Electricity in passing through the body modifies the nameless and numberless phenomena every moment going on in the living tissue, and as a resultant of its complex physical, chemic, and physiologic action there is improved nutrition and increased development and growth.

For the production of such effects experience amply testifies to the superiority of the current under consideration to any of the others. For the relief, therefore, of that great army of symptoms that are so familiar and perplexing to those who have much to do with neurasthenic cases, there is nothing to be compared with it. Even the galvanic current, by the method of central galvanization, so important in its direct effects upon the central nervous system, falls short of the therapeutic results that follow through applications of general faradization.

When persistent failure follows endeavors along this line of electrization, the cause of failure must be attributed to hasty and faulty methods of administration. Even more marked is the difference in the action of this current of tension and the current of quantity in bipolar faradization of the rectum, vagina, and uterus. Its comparatively mild action on the motor and sensory nerves, coupled with its great power of overcoming resistance, render the current of tension *par excellence* the current for the relief of pain.

While the currents from the first two coils act but feebly when applied externally, but with astonishing vigor when applied internally, the current of tension from the whole combination of coils acts with a vigor that is felt through all portions of the system when applied externally, yet when applied to the uterus through a bipolar electrode its action is but slightly felt, and is without disagreeable sensation. So tolerant, indeed, are the internal muscular organs of the body to the induced currents of tension that it is absolutely impossible to obtain a current of sufficient power from the batteries in ordinary use. Batteries that have been long in use and that are illy kept, while perhaps yielding a current of tension of sufficient strength for localized applications externally, are insufficient for bipolar applications. Even if at first the current is appreciably felt in the uterus, the sensitiveness soon subsides although its strength may have been very much increased, and both physician and patient may be in doubt as to whether the current is being received at all.

This phenomenon becomes prominently apparent in hysterical cases with which is associated excessive hyperæsthesia of the abdomen, and it has been no uncommon thing in my observation to treat women with the current of tension for the relief of the most acute surface abdominal hyperæsthesiæ, and at the close of a single *séance* to find the abdomen insusceptible to any ordinary manipulation. Far different is it with the current of quantity. Tolerance is not established, and what is painful in the beginning continues more or less painful throughout the treatment, and it frequently becomes necessary to decrease rather than to increase the current strength. To avoid the disagreeable shock, of which the patient invariably complains even when beginning the application with the minimum of current strength, a rheostat should be intercalated. With the modern high-tension coil, however, a rheostat is not necessary, since its construction is such that the current begins from absolute zero.

The main points that have been considered are these:

1. From the ordinary continuous-coil apparatus, owing to its combination of helices, the wires of which differ in thickness and length, proceed

four qualities of current that vary in a most remarkable degree in all the properties of electricity—physical, physiologic, and therapeutic.

2. That the variation is observed most markedly when applications are made internally to the vagina, uterus, rectum, or bladder, by the bipolar method.

3. From the primary or first induction coil we obtain a current of quantity that is barely perceptible externally, but internally, and especially by the bipolar method, acts with greatly increased efficiency.

4. From the combination of the primary and secondary induction coils we obtain a current of greater tension, but which still acts mildly when applied externally. Applied internally, however, its effects are far greater than the first coil, both in exciting the sensibility and contractility, and the utmost caution must be exercised in its use. In the same degree, also, it acts upon the vagina, rectum, bladder, and testes. This current is especially applicable in the treatment of enlargements of the uterus due to subinvolution, but is of little or no value when the enlargement is due to fibrous tissue. It is of especial value in post-partum hemorrhage, and from its power to excite the sensibility and contractility of the bladder and rectum it may be used with good effect when these organs are anæsthetic or suffer from diminished or lost contractility.

5. From a combination of the first, second, and third induction coils we obtain the maximum of power to excite both sensibility and contractility on the external surface of the body, each additional coil, provided the initial force or voltage is not increased, simply giving a decreasing power over sensation and contraction. Applied internally, however, it acts far less powerfully than either of the two previously named currents; but in the ordinary forms of paralysis of voluntary muscles it will more readily call for the contractions than the current from any other combination of coils.

6. From the first, second, third, and fourth induction coils combined a current is obtained, differing from and superior to all the others in its sedative and general tonic effect upon the system at large. It neither acts upon the sensibility or muscular contractility when applied externally as does the third current of the series, nor with a tenth nor even a twentieth part of the acuteness when applied internally, that characterizes the second current of the series. For the purposes of general faradization, however, it is the only proper current to use, and for applications to the vagina and uterus, for the relief of many forms of pain, it possesses properties that are invaluable.

CHAPTER XVI.

NEURASTHENIA* AND ALLIED AFFECTIONS.

FUNCTIONAL diseases of the nervous system and indeed all functional derangements are of far greater importance in the consideration of methods of relief than diseases that are organic or structural. Volumes have been written about progressive degeneration of nerve tissue, yet we still find that all our therapeutics avail but little in dealing with gross central or peripheral nerve lesions. A man suffering from a grave structural lesion is very much in the same condition of him who is in a state of senility. "The house is tumbling to pieces; the landlord refuses to make further repairs," and unassisted by nature medical art is practically powerless. With what, however, in our ignorance we term functional diseases, the case is widely different. Nature here does not withhold her aid and supplemented by the resources of science the most distressing and persistent functional diseases are successfully dealt with. Of all forms of the functional neuroses, neurasthenia is perhaps the most important, not alone because of its frequency and the suffering that it entails, but because the results of treatment are so much more gratifying than in many of the diseases belonging to this class. The derivation of the term neurasthenia is sufficiently obvious. It comes from the Greek word *νευρον*, a nerve; *α*, privative; and *σθενος*, strength; and therefore, being literally interpreted, signifies want of strength in the nerve. Under the name of general debility, it is a condition sufficiently familiar to every practising physician, and too frequently resists most obstinately all forms of internal medication. It is not to be confounded with anæmia, though it may be associated with it.

The one principle on which neurasthenia is to be treated is by the concentration of all possible tonic influence on the nervous system—air, sunlight, water, food, rest, diversion, muscular exercise, and the internal administration of those remedies, such as strychnine, phosphorus, arsenic, etc., which directly affect the central nervous system.

Electric Treatment.—The best methods of using electricity in the treatment of neurasthenia are undoubtedly general faradization and central galvanization, but if there be special or local disorder as prostatic or

* See treatise on this subject by Drs. Beard and Rockwell.

ovarian irritation, then local faradization and galvanization are also required. Static electrification sometimes gives better results than either galvanization or faradization. The differential indications for the use of the dynamic or static forms of electricity in neurasthenia can be determined only by a study of the idiosyncrasies of individual cases.

Beneficial results are so uniform in this condition that we have reason to suspect some unrecognizable organic disease in those cases that give no evidence of improvement after protracted treatment. Even the complicated forms, that are the result of incurable disease, may be much relieved. The cases that fail to be benefited by electric treatment are those of lifelong standing, or in which the temperament contraindicates electric treatment.

Spinal Irritation.—Spinal irritation is one of those names which, like hysteria, have become the recognized property of the profession, against the actual or implied protest of nearly all who employ it. It is a part of the hysterical constitution.

The term spinal irritation, originally proposed by Dr. Brown, of Glasgow, and described and illustrated in detail by G. T. P. Teale, in 1829, and the Griffin brothers in 1844, is now pretty generally understood, in England and America at least, to express a tolerably well-defined morbid condition, of which one of the principal symptoms is spinal tenderness.

Differential Diagnosis.—Spinal irritation almost always forms a part of hysteria and neurasthenia, constituting, as it were, a subdivision or accompaniment of them, and is only entitled to the honor of distinct nomenclature by itself when the spinal tenderness and the symptoms that directly flow from it overshadow other accompanying conditions. Close examination would reveal that very many of the cases in practice that are variously classified under hysteria, anæmia, etc., have a sufficiently marked tenderness of the vertebræ to be regarded as examples of spinal irritation; and if treated accordingly, would recover more rapidly than under the methods usually employed. The best confirmation of the diagnosis is the very favorable result of judicious and varied treatment devoted specially to the tender spots on the spine.

Between spinal irritation and spinal meningitis or congestion the distinction is oftentimes purely one of permanence and degree. In both conditions there may be pain and heat in the spine, neuralgia or paralysis of the limbs, plantar heat and anæsthesia, constipation, feeling of pressure or constriction in the chest, and stiffness of the neck, etc. It is distinguished from myelitis by the absence of other necessary symptoms. The contractions of muscles in spinal irritation are less painful than those of myelitis.

Pathology.—In spinal irritation, as in cerebral irritation, it is probable that there may be either anæmia or hyperæmia. That many of the cases of spinal irritation depend on passive hyperæmia of the cord is rendered probable—

1. By the feeling of heat and burning at the seat of the irritation.

2. By the fact that this pain is increased at night, when the patient is in a recumbent position.

3. By the fact that it is relieved by measures that relieve congestion, as dry and wet cupping, and by blisters over the tender vertebræ.

On the other hand, reasoning from analogy and from what we know of the relation of the sympathetic, it is proper to assume that anæmia may account for many of the phenomena of spinal as of cerebral irritation. This assumption is strengthened by the fact that very many of the patients who have spinal irritation are more or less anæmic. And yet, reasoning from the history of the cases and from the results of treatment, we are inclined to the opinion that anæmia exists only in a minority of the cases of spinal irritation; that in the majority of instances there is more or less at least temporary passive congestion of the cord and of its membrane; and that in all cases of doubt it is safe to assume the existence of hyperæmia, and to guide the treatment accordingly.

It is not necessary to assume that this hyperæmia of the cord is a constant condition. Except in the severe and long-standing cases, it is probably not so, but is more or less evanescent, temporary, and metastatic. This may distinguish it from spinal congestion, which is a fixed condition. Temporary congestion of the cord, as of the brain, the genitals, the eye, and the ear, may perhaps be easily excited by irritating causes. It is not unreasonable to suppose that anæmia and hyperæmia may alternate in the patient, and in the same day or hour.

Electric examination in spinal irritation may sometimes reveal tender spots on the spine that are not indicated by pressure.

Treatment.—Electric treatment consists in general faradization, galvanization of the spine and sympathetic, and central galvanization.

Our experience in a great number of cases, since the first edition of this work, convinces us that in galvanization of the spine the positive pole acts better than the negative in the treatment of this affection. To depend, however, on localized galvanization alone is illogical, since the disease, though for the time specially localized in the spinal cord, is usually simply but a development or manifestation of the nervous diathesis, in which the whole system shares.

Prognosis.—Under electric treatment alone, the prognosis of spinal irritation is usually favorable for a relief, and sometimes for permanent cure.

It is, however, of great advantage in all severe or long-standing cases, to combine with electrization counter-irritation (very small blisters, or tartar-emetic ointment) over the sensitive vertebræ, and the internal administration of phosphorus or other stimulants.

Comparative rest of brain and muscles is an important, though not indispensable, aid to treatment. The disease is quite prone to relapse, especially under bad hygienic surroundings. Under combined treatment, consisting of blisters to the spine, phosphorus, strychnia, and electrization, the majority of cases will rapidly improve.

Insomnia.—Insomnia is a symptom which, with greater or less uniformity and severity, accompanies nearly all forms of disease.

It is a symptom of such an indefinite variety and complexity of pathologic conditions that it is manifestly impossible to treat it with anything like uniform success by any one conceivable form of medication; but of all the remedies that have yet been tried there is, we believe, no one which permanently relieves the symptoms in so large a proportion of cases as electrization. The effects of electricity on the sleep, whether used in the form of general faradization, galvanization of the head and cervical sympathetic, or static electrification, are both temporary and permanent. The temporary relief that appears the night or two following an application, though usually far less potent than those of bromide of potassium and hydrate of chloral, are yet very decided; but it is for the permanent relief that electrization is chiefly indicated in this symptom. This comes gradually, slowly, and as a result of the improvement of the morbid condition on which the insomnia depends.

As has been stated, improvement in sleep is one of the earliest effects for which we look during a course of treatment by general electrization. In a wide range of diseases sleep, to a certain extent and with exceptions, may be regarded as a thermometer of health. When all other bodily functions are well performed, the sleep is usually sound, calm, and refreshing; when it becomes painfully and persistently disturbed by dreams, or is long absent, we may suspect actual or approaching disease.

Temporary loss of sleep, that comes from temporary anxiety or from neuralgia or other pain, is usually relieved with the removal of the cause, and only demands special medical treatment when it is long continued.

The treatment of insomnia is really the treatment of all the diseases on which it depends. For those cases where simple wakefulness exists, unaccompanied by any other symptom of recognizable disease, we may use either galvanization of the sympathetic, or faradization of the head and spine, general faradization, or what is in some cases more effective than all, treatment by static insulation. By the last method, positive insulation is to be preferred to negative.[1] It is not even necessary to make the applications to the head, the sympathetic, or even to the spine, in order to produce sleep. Simple peripheral galvanization or faradization will produce this result, and in some cases to a very marked degree. This must, we suppose, be explained by reflex action. In a case of rheumatism of the hip-joint, which we once treated by galvanization through the joint, the soporific effect on the patient was so marked that he fell into a profound slumber before we had time to leave the house, in less than ten minutes after the application was over. In another case of infantile paralysis the mother reported that the child slept soundly for two hours or more after each sitting, although only the limbs were galvanized.

Astraphobia (ἀστραπή, lightning, and *φόβος, fear of).*—Some individuals, especially those of peculiarly impressible organizations, are not only unpleasantly but seriously affected during thunder-storms that are attended by vivid flashes of lightning. They suffer not only distressing fear, but positive pain in the head or stomach, that leaves them in a condition of exhaustion that may last several hours, or even two or three days.

A medical friend informed us of a patient under his care, who during thunder-storms was attacked by severe nausea, and by convulsive attacks resembling epilepsy. Under treatment directed to the improvement of her general system she greatly improved. In some cases diarrhœa is excited.

These symptoms, though most frequent with nervous people, and especially with women, may also appear in those who are otherwise strong both in health and in will power.

In several cases of astraphobia of long standing we found much diminution of volitional contractility and considerable anæsthesia, but no loss of electric muscular contractility.

Treatment by the electric brush and central galvanization afforded much although not absolute relief.

Hysteria.—That electricity is not generally appreciated as a valuable remedy in the treatment of hysteria is due to the fact that the profession have looked upon electricity as a stimulant merely, and have not fully recognized its sedative and tonic properties, and hence have confined their attention largely to paralysis, as the one disease above all others to be treated by this agent.

Electro-diagnosis.—Usually, though not necessarily, there is excessive sensitiveness to the electric current in all parts of the body. Patients sometimes can bear only the mildest currents. In some cases even a mild current will not be borne on the middle of the back, which, in health, is usually so little sensitive. Reflex sensations may be observed during electrization of hysterical patients. Irritation of the diseased side of the body may be sensitively felt in the healthy side. Sometimes there is capacity for bearing very strong currents without injury, even when there is great hyperæsthesia. The electro-diagnosis of hysterical paralysis will be presented under that disease.

Treatment.—Hysteria is a constitutional disease, and demands constitutional treatment. To attempt to chase after and direct the application of electricity to each special symptom as it appears, is unphilosophical and usually unsuccessful. General faradization, central galvanization, and static electrification are methods of electrization that are indicated for hysteria. Under whatever symptoms it may be developed, our chief and best results have been obtained by these methods. This general treatment does not, of course, dispense with localized electrization of paralyzed muscles, or special attention to any localities where the disease is for the time directed. Diseases of the sexual organs, hysterical hiccough or cough, aphonia, or incontinence of urine, may sometimes need localized electrization; but these symptoms frequently yield under general faradization or central galvanization, even when no special attention is given to the diseased parts. In nearly all cases, except, perhaps, long-standing paralysis, it is much better to dispense with the local than the general treatment. There are cases, however, in which the symptoms of rigid contractions of certain muscles are most persistent and painful in character. In such conditions of the affected muscles galvanization should never be omitted. In cases of extreme hyperæsthesia it may be necessary, as Benedikt advises, to place the patient under the influence of an anæsthetic while the application is made. Strong currents do not appear to be injurious in such cases.

Prognosis.—The behavior of hysteria under electrization is as capricious and inconsistent as are its symptoms. Some cases yield to general electrization with wonderful rapidity; others, apparently no worse, are singularly obstinate. On the average, the prognosis is so favorable that no case should be abandoned without a fair trial of this method of treatment. Under peripheral electrization the results are usually unsatisfactory, since the relief of the local symptom is by no means a cure of the morbid constitutional condition.

Hysteria illustrates as much as any other disease perhaps, first, the extraordinary tolerance in a highly nervous patient of the galvanic current; and secondly, the supreme advantage of central galvanization over general faradization in severe functional diseases of the central nervous system. In many of these cases it is no uncommon thing for the patient to bear without the slightest discomfort 50 to 60 milliamperes of current.

Hysterical and analogous symptoms are both associated with and dependent upon recognizable uterine disorders, but in many cases, while these symptoms may be associated with and aggravated by such disorders, they are not by any means always dependent upon them.

During our service at the New York State Woman's Hospital we found that symptoms of excessive nervousness, etc., which were supposed to be merely a reflex of local derangement, have frequently yielded to some form of electrization, before any manifest change has been observed in the condition of the sexual apparatus.

Hypochondriasis and Melancholia.—The distinction between hypochondriasis and melancholia is vital. The hypochondriac readily appreciates the character of any special disease from which he may suffer, but he has a most exaggerated conception of its importance and of its probable results. He talks much of his symptoms, and unceasingly seeks relief. The melancholic, on the contrary, possibly suffers from no appreciable disease; or if any evident structural or functional trouble exists aside from the recognized mental perversion, it is unheeded. As Maudsley expresses, "the former committing a murder would certainly be hanged, the latter probably not." The tendency of the melancholic is frequently to suicide —the hypochondriac clings to life. Intellectual exertion is an impossibility for the melancholic; the hypochondriac, on the contrary, may lead the highest intellectual life.

The one suffers from such perverted habits of thought and feeling that the strongest and most natural affections may cease to exist; the other retains all the normal warmth of feeling toward friends and relatives.

Melancholia is a more advanced phase of mental perversion, and to this advanced and more serious condition hypochondriasis not unfrequently progresses.

There are reasons for believing that the sympathetic nervous system is largely at fault in cases of hypochondriasis; and that if not demonstrably diseased it is yet the medium through which disease of the other parts reacts on the brain, and produces molecular or other disturbance.

The two leading ideas that we here desire to impress are, first, that hypochondriasis is just as truly a disease, or, more strictly speaking, a symptom of disease, as dyspepsia, insomnia, chorea, neuralgia, paralysis, or insanity, and should be treated accordingly. The popular method of neglecting hypochondriacs altogether, or of administering placebos, is not scientific, and, except in rare cases, is not successful. Secondly, hypochondriasis, when not dependent on serious lesions of the central nervous system, is susceptible of relief and of positive cure under the skilful and faithful use of electricity. Still further, we believe—and the results of our own cases justify the belief—that cerebral disease of a more pronounced character itself may be relieved by electricity; and that that terrible form of hypochondriasis which is the precursor of organic cerebral disease—the vestibule that leads to the dark and gloomy caverns of insanity—may be controlled or kept at bay by a persevering electric treatment.

Treatment.—In hypochondriasis, general faradization, central galvanization, galvanization of the cervical sympathetic, and static electrification, are indicated. We have obtained good results from all methods, though most of our cases were treated by the first and second.

Insanity.—We have seen that very much has been accomplished in the treatment of neurasthenia, hysteria, and melancholia by the combined methods of central galvanization, general faradization, and static electricity, and, reasoning from analogy, it is probable that an important future is in store for the scientific, faithful use of these methods of electrization in our public and private asylums.

It is not as well recognized as it should be that in diseases of the brain and spinal cord, where the mind is seriously affected, the electric treatment is also indicated, just as in diseases of the same organs when the mind is not affected. In some of the asylums of England, United States, and Germany, electricity is now and for some time has been used as an adjunct to other remedies for the treatment of different forms of insanity; but with a few exceptions, the treatment is not systematically carried out, and, partly through ignorance of the methods of application, partly through want of sufficient medical assistance to supervise the necessary details, the results have not been entirely satisfactory, and the cases have not been fully recorded.

The failures in this as in other branches of electro-therapeutics are, in fact, the logical result of want of familiarity with the management of batteries, of incorrect ideas on the differential action of the currents and the general action of electricity on the body, and deficient technical skill in the details of the applications.

For those who are beginning to use electricity, or are contemplating its use in the asylums for the insane, these general suggestions may be of service: 1. Let it be remembered always that electricity, in any form—franklinic, galvanic, or faradic—when applied to the body, acts as a stimulating tonic with a powerful sedative influence. It is an agent for improving nutrition in any condition, local or general, where improvement in nutrition is required. It is to be used for the insane just as bromide of potassium, quinine, strychnine, and iron are used.

The order and degree of its effects depend largely on the method and manner of application, and on the constitution and disease of the patient to which the application is made.

2. That in insanity the brain is not the only part of the body affected. Excluding those cases of insanity produced by reflex action from the digestive and pelvic organs, there are very many cases where the spinal cord and other parts of the central and peripheral nervous system suffer as an effect of the disease of the brain.

While these remarks may seem but commonplace to experienced psychologists, and while the fact of the relation of diseases of the brain to diseases of other parts of the body is continually recognized, when other remedies are employed, still, in the application of electricity, some experimenters have acted on the theory that the brain alone should be treated. Those who act exclusively on this theory will not gain great victories over insanity by electricity. Some of the applications should be made in such a way as to bring the whole central nervous system under the influence of the current, and local diseases associated with insanity as a cause or effect should receive local treatment.

The central nervous system is best brought under the direct influence of the galvanic current by the method of central galvanization. The method may be varied by galvanization of the brain, cervical sympathetic, pneumogastric, and spine; but the method of central galvanization is easier, safer, and more effective. In cases associated with debility, and especially in those forms of insanity dependent on neurasthenia or nervous exhaustion, general faradization answers a good purpose, and may with great advantage be used alternately with central galvanization or localized galvanization of the nerve-centres.

3. The first tentative applications should be very mild, and the strength of the current and the time of sitting should be gradually increased as the patient proves himself able to bear the treatment.

In an article on the "Early Treatment of Insanity," Dr. D. R. Brower writes that "Electricity, especially galvanism, by reason of its alterative and tonic properties, is generally indicated. It is best used first as cephalic galvanization, by placing the anode at the forehead and the cathode at the nucha, using large electrodes, with a current strength of three to five milliamperes, for about five minutes; and second, by galvanization of the cervical sympathetic, by placing the cathode over the cervical sympathetic ganglia and the anode at the nucha, and using five to ten milliamperes of current for about five minutes. Static electricity from a machine of high voltage, used as insulation for five to ten minutes, and then as induced sparks, from the spinal region, every day, is often very useful."

CHAPTER XVII.

NEURALGIA.

The relief of pain, whether of a pseudo-neuralgic or hysteric character, or whether dependent on true neuralgia or other causes, is a very important function of electrization; but in no condition has it been more difficult to discriminate correctly in the selection of the proper method of electric treatment. True neuralgia, as defined by Anstie, is without doubt most successfully treated by the galvanic, while hysterical neuralgia, and the so-called pseudo-neuralgia, which are simply forms of pain, occupying certain areas, and running seemingly in the direction of certain nerves, yield most readily to the faradic current.

More specifically, the effects of pressure in the various forms of neuralgia are exceedingly useful, as guiding symptoms, indicating the proper current. We do not by any means lay it down as a universal law, but it will certainly be found that, in the great majority of cases of neuralgia, where firm pressure over the affected nerve aggravates the pain, the galvanic current is indicated, while the faradic current has the greater power to relieve when such pressure does not cause an increase of pain.

In the class of cases called sometimes hysteric hyperæsthesia, it is well known that firm and prolonged pressure affords marked relief, while pressure superficially applied increases the distress. The faradic current is here infinitely superior to the galvanic.

Electro-diagnosis in neuralgia discovers the painful spots that are detected by pressure in the course of the affected nerve, and may also discover sensitive points on the spine, or the head, that might, perhaps, have otherwise escaped observation.

Treatment.—Before attempting the electric treatment of neuralgia, we should endeavor to diagnosticate its general character, in order to decide upon the method to be employed. In doubtful cases it is necessary to try in succession central, peripheral, and general treatment.

The treatment of the different varieties of neuralgia is the best test of skill in electro-therapeutics. There is no disease or symptom in which the results of treatment in different cases so closely depend on the nature and strength of the current used, and the method and frequency of the applications.

Cases that injudicious treatment might aggravate may, by the exercise of the skill and caution that experience teach, be rapidly cured.

The success achieved by electrization in the treatment of neuralgia has been brilliant and remarkable, and would be sufficient of itself to entitle it to a prominent and indispensable position among modern remedies. What is more remarkable still is that this success has been achieved by very diverse methods of applications, and with imperfect, indifferent, or incorrect diagnoses. All forms of electricity—static, galvanic, and faradic—in all the different methods and phases of electrization, general and localized, centrally and peripherally, by currents, stable, labile, continuous, interrupted, uniform, and increasing.

The pain is frequently relieved in the midst of the application; but in such cases it usually returns in the course of a few hours, and sometimes with heightened intensity. Some cases of a peripheral character are permanently dispelled by one or two applications.

Electricity is applied for neuralgia in the following forms:—

General faradization and central galvanization.

Localized faradization or galvanization, central or peripheral, or both combined.

Galvanization of the cervical sympathetic.

Cataphoresis.

The sinusoidal current.

Electric brush.

Electric moxa.

Static electricity.

Electric bands and disks.

The magnet.

Static electricity works well in neuralgia, and excellent cures have been performed by it, but it is inferior to both the galvanic and faradic currents.

Many of the failures and disappointments with the use of electricity in neuralgia have been due to the mistake of treating constitutional diseases locally, and the central varieties peripherally.

There is one difficulty in the treatment of neuralgia by electrization, and that is that, on account of the intensity of the pain of the disease, patients are sometimes unwilling to give the treatment a fair trial. This difficulty is further increased by the fact that, during or after the first two or three applications, the pain may be temporarily aggravated, especially if the sittings have been long, or with currents of too great strength. For this reason the initial applications should be made with caution, and the operator should not yield to the temptation to renew them too frequently. Once a day, or every other day, is about as often as applications can be made with benefit.

As before remarked, the methods of applying electricity must be studiously adapted and varied to each case, ever keeping in mind that all methods of using electricity have been successful in this disease, and that no one method is uniformly successful even in the same variety.

Besides the central and general electrization, which is to be conducted on general principles, in order to affect the seat of the disease, all the varieties of neuralgia may demand more or less treatment in the seat of the pain. For this purpose we may use either faradic or galvanic currents. Although the faradic achieves excellent results, yet some of the most striking results have been obtained by the galvanic. It sometimes relieves the pain when the faradic only aggravates it.* After the faradic current has been tried a few times without effect, we should never abandon the case without resorting to the galvanic, or the two currents may be used alternately. As a rule, the applications should be short and made with a mild current; but this rule has marked exceptions. Idiosyncrasies and individual susceptibilities are important factors, so that the length and strength of applications vary from a few moments to half an hour, and from two or three milliamperes to fifty or sixty and more. There appears to be no special law in regard to the direction of the current. The strong statements that have been made in regard to the superiority of one or the other pole in this disease are not sustained by experience. Either the positive or the negative pole may be placed over the painful points, while the other pole is applied near or on the nerve-centre. Thus, in neuralgia of the arms, one pole may be placed at the cilio-spinal centre, and in neuralgia of the legs on the lumbar vertebræ, and the other on the affected nerve (spinal-cord-nerve current).

The sinusoidal current acts exceedingly well in many cases of severe neuralgia, and in some cases may prove more efficacious than the ordinary faradic current. It is certainly superior for the relief of pain to the somewhat irritating current yielded by some induction coils. We have not, however, found it superior in efficiency to the current from the modern high-tension coils, and is by no means equal to the galvanic current in the treatment of severe neuralgic cases.

Cataphoresis is sometimes successful after the failure of ordinary methods. This was well illustrated in a recent case of supra-orbital neuralgia, in which the use of a ten-per-cent. solution of cocaine completely relieved the pain for many hours, after the failure of the applications of heat, the cautery, and various methods of electric application.

The electric moxa is sometimes more rapidly efficacious in neuralgia than any other method of treatment. It is, however, a very painful procedure, and many patients will not bear it. It seems to act partly as a counter-irritant. Meyer very strongly advocates the use of electric moxa in neuralgia, and sustains his position by a number of cases. Very few American patients in the higher walks of life will bear this severe method of using electricity.

* The statements of Niemeyer and others that the faradic current never succeeds in neuralgia after the galvanic fails, is not true. We have seen several cases where relief was obtained by faradization, after galvanization had at least apparently failed.

General Prognosis.—Take the cases as they arise, without reference to their pathology, duration, or situation, neuralgia offers a very favorable prognosis. The majority of cases will be cured or permanently improved. Patients who have the neuralgic constitution are liable to relapse in time, however successful the treatment may have been.

Central Neuralgia.—Under this head we include those cases of neuralgic pain that certainly depend on pathologic lesions of the central nervous system.

The neuralgic pains of locomotor ataxia belong to this class. Those who with Dr. Anstie regard neuralgia as a distinct disease, dependent on atrophy of the roots of the nerves, do not regard these pains as really neuralgic. Under this class also come certain varieties of headache and cervical neuralgia.

Cephalalgia (*Headache*).—Headache should be treated by general or localized electrization, according to the indications of each case. Dry faradization with the hand is used successfully. Stable galvanization or faradization, uniform or increasing, may be employed. Labile applications with the moistened hand are sometimes of service. General faradization is more effective than localized, for the reason that in so large a proportion of cases the pain in the head is so very frequently symptomatic of disease of other parts of the body, the precise nature and locality of which we cannot possibly detect. Central galvanization is sometimes more efficacious than any other method. Relief not unfrequently follows galvanization or faradization of the stomach, or bowels, or spine, or galvanization of the sympathetic, even when the head is not touched. Applications to the back of the neck are sometimes more efficacious than direct applications to the head.

Prognosis.—Although headache in this country is even a more frequent symptom than dyspepsia, yet patients do not usually apply for treatment for this symptom alone, but only when it is associated with more special and distinct affections. The immediate effects of electrization in headache are as variable as the pathology of the symptoms. It sometimes relieves, sometimes aggravates, and sometimes gives only negative results. Sometimes the pain is relieved in the midst of the sitting; more frequently the relief does not appear for several hours. There is no reason to be discouraged because immediate relief is not obtained. In very many of our cases of dyspepsia, of anæmia, chlorosis, nervous exhaustion, paralysis, headache is a more or less constant symptom, from which during the treatment the patient usually obtains either relief or cure. In rare cases all other symptoms yield but this.

In many of the cases of dyspepsia, neurasthenia, anæmia, and hysteria, headache was a prominent symptom, which was not only temporarily but permanently relieved by the treatment. If we were to judge from our own observations, electric treatment is even more efficacious to prevent attacks of headache, by improving the tone of the system, than to dissipate the pain after it has once set in.

The Magnet.—The therapeutic results that have been obtained by the magnet in the treatment of headache are not sufficiently encouraging to entitle it to special notice. Something has been claimed for it, but evidently the results that follow its use are purely psychical.

Sick Headache (*Migraine*).—The relief afforded by any form of electrization in sick headache is not great.

The true principle of treatment is to tone up the system by a persevering use of general faradization, central galvanization, or static electrification, with other tonics, so that the paroxysms may be less frequent and less severe; in other words, to combat the nervous diathesis of which the sick headache is but a symptom.

Trigeminal or Facial Neuralgia.—Facial neuralgia appears under two forms. The mild form is peripheral and usually yields readily and surely to electrization. The severe form, to which Trousseau has given the name epileptiform neuralgia, is probably of a central character, being caused by a variety of pathologic conditions of the brain.

The symptoms of this form of facial neuralgia are the spasmodic and very intense character of the pain in the course of some of the branches of the fifth pair. The spasms are of very short duration—ten to fifty or sixty seconds—and may be accompanied by convulsive action of the muscles. The attack may be brought on by any exercise of the jaws, as chewing, reading, eating, or talking. The pain is so great as to cause the patient to slap his face, or frantically rub the spot over the seat of the pain. Sometimes patients who have great self-control stamp violently on the floor, jump up if they chance to be sitting, pace the room, and utter piercing cries.

Tic Douloureux.—This terrible disease has usually been regarded as almost incurable, and is so pronounced by Trousseau, who has graphically described its symptoms.* Section of the nerve, of which so much was once expected, is now but seldom used, and permanently succeeds only in exceptional cases.

By a judicious and varied use of peripheral faradization or galvanization, or by the electric moxa, or by galvanization of the brain or cervical sympathetic, a certain portion of these terrible cases can be relieved or cured. Our experience does not enable us to say what proportion the failures will bear to the successes; but if one case out of ten can be relieved or cured, it is justifiable to try electricity in all, since most other modes of treatment offer no hope.

Peripheral Neuralgia.—Neuritis, neuroma, the continued action of cold or wind, wounds, or other injuries of the nerve—all these may give rise to

* See his Lectures, Bazire's Translations, part 1, p. 105.

the peripheral form of neuralgia. Neuritis, or rather inflammation of the neurilemma, must be regarded as one of the most frequent causes of peripheral neuralgia, and this inflammatory condition may depend upon some form of mechanical irritation, as long-continued pressure of the child's head in labor on the sciatic plexus, or by the concentrated poison of gout, rheumatism, malaria, or syphilis, acting locally. It may, of course, be conceded to the advocates of the purely central theory of neuralgia that there may be a constitutional predisposition to neuralgia, but, on the other hand, it must also be conceded that, in many cases at least, some exciting cause, acting on the periphery, is necessary to develop it.

Treatment.—The treatment of peripheral neuralgia should obviously be of a peripheral character; stable faradization and galvanization, and electric moxa. In doubtful cases, that refuse to yield to this method of treatment, it is well also to try central and general electrization.

Gastralgia.—Gastralgia may perhaps be included under peripheral neuralgia, although there is room for much discussion on this point. Our results in gastralgia have thus far been more satisfactory than in any other neuralgia.

Sciatica.—In the treatment of sciatica by electrization very much depends upon the care with which the current is applied. An ill-directed, too prolonged application, or the use of a current the mechanical effects of which are unduly marked, frequently results in more harm than good. In sciatica, the pain, as a rule, closely follows the course of the nerve, and, therefore, in the majority of instances the disease is typical of true neuralgia. The effects of faradization in these cases are undoubted, and in our hands have sometimes proved far more efficacious than galvanization.

It cannot be too frequently repeated, that in sciatica the faradic current is capable of doing infinite harm if ignorantly used or over-used, but that if applied with that caution and skill which experience alone can give it generally relieves.

It is in just such conditions as these that the character of the current for fineness and evenness is all-important, and these factors are found combined in a higher degree in the high-tension coil than in any other. On account of the great caution that must be exercised in the treatment of sciatica by faradization it is probable that beginners may here achieve greater success through the use of galvanic currents. The muscular atrophy that sometimes follows sciatica may be treated by localized faradization. Whichever current is used the application should be made both over the lower part of the spine, to act upon the roots of the nerves, as well as over the course of the nerve in the leg.

Galvano-Puncture.—We have attempted the treatment of sciatica by electro-puncture.

The needle may be insulated or not; should be bayonet-shaped, so as to go in easily, and may be inserted far enough to touch or penetrate the nerve. The moment when it so penetrates or even touches will be revealed to the patient by a tingling or pricking sensation through the leg.

The needle thus introduced should be connected with the negative pole; but one or two cells should be used, and the current should be continued but a few minutes.

In the treatment of sciatica by the galvanic current it has for some years been our experience that in the majority of cases strong currents from 30 to 60 milliamperes give the best results. With large electrodes, indeed, and with some such plastic material as sculptor's clay we have not infrequently applied a current strength of 75 and 100 milliamperes to the great benefit of and with no discomfort to the patient.

Herpetic Neuralgia.—Herpetic neuralgia wherever situated is usually accompanied by pain of greater or less severity. Whether its seat be the head, the trunk, or the extremities, the associated pangs are sometimes almost beyond human endurance.

Herpes is now generally regarded as subordinate to the existence of a neuralgic or rheumatic diathesis, and as originating in any cause which weakens the vigor of a nerve-trunk or its cutaneous branches: hence it would not be unreasonable to suppose that electricity in some one of its forms might prove of service.

The teachings of experience clearly attest its value in this complaint. The disease, it is true, runs an acute course, and, as a rule, recovery more or less complete follows in the course of a few weeks, but it is none the less incumbent to relieve, so far as possible, the acute sufferings that attend it.

Our experience in the treatment of this disease leads us to the following conclusions:

1. That the pain of herpes, no matter where the seat of the eruption may be, is generally susceptible of speedy and effectual relief by the use of the galvanic or faradic current.

2. That when the eruptions take place on the head—herpes frontalis—the galvanic current has greater power to relieve the pain than the faradic.

3. The electric treatment, besides relieving the pain of herpes, seems to shorten somewhat the acute stage, to break the force of the disease, and to modify the scarring.

Galvanic belts and disks have been recommended for the treatment of neuralgia, but the objections to and disadvantages of this method of treatment in neuralgia, as in all other affections for which it has been so widely employed, are these:

1. The current which they generate is very feeble and inconstant, and probably does not, except under peculiarly favorable circumstances, penetrate far beneath the epidermis.

2. They can only be used locally. Many of the symptoms for which

they are used are of a constitutional character, and can only be permanently dispelled by measures calculated to affect the whole system.

3. They are usually, and sometimes necessarily, applied to the seat of the pain rather than to the seat of the disease. In galvanization and faradization for local neuralgia, it is found that the best results are obtained by treating the seat of the disease.

4. They sometimes cause ulcers that leave permanent cicatrices.

The benefit that is derived from them is probably due in part to their influence on the imagination.

These arguments against the use of galvanic belts would be valueless, if experience could demonstrate from their use any great utility or any very positive advantage.

It is not impossible that, in future improvements in the construction of these belts and chains, and more scientific experiments in their use, we may develop advantages from them which they have thus far failed to exhibit, and may accord to them a position in electro-therapeutics to which, from the results of the past, they are not entitled.

The fact that they have thus far been used almost exclusively by the laity, and have been made the theme of noisy advertisements, so far from discouraging, should rather stimulate men of science who have any faith in their efficacy to rigidly investigate and interpret their claims to a position among the appliances of electro-therapeutics.

Those, however, who experiment with these contrivances should remember that the mechanically irritating effects of metallic bands applied to the tender skin are not inconsiderable, and that the therapeutic results which appear to follow their application may not unlikely be due wholly, or in part, to counter-irritation.

CHAPTER XVIII.

PARALYSIS.

Paralysis of motion is a condition for which, from the earliest history of electro-therapeutics, electricity in its different forms has been used more than in any other disease; and not until quite recently has it been demonstrated that there are many other symptoms in which the results of electric treatment are much more rapid and brilliant than in any form of motor paralysis. In neurasthenia and affections allied to it, in cerebral and spinal congestion, in chronic alcoholism, neuralgia, in certain diseases of the skin, and in many of the diseases of women, electricity rightly used relieves and cures far more rapidly than in paralysis.

Paralysis has been especially prominent in electro-therapeutics, for the reason that oftentimes electricity is the only remedy to which it yields. Those who have restricted themselves to localized electrization have always given their chief attention to different forms of motor paralysis, but even now the impression yet lingers that it is about the only disease for which electricity is indicated.

All forms of paralysis, as of neuralgia, may, for the sake of convenience of description of therapeutic indications, be included under one of these four divisions:

1. Constitutional.
2. Central.
3. Peripheral.
4. Reflex.

Constitutional Paralysis.—This term is applied to those paralyses which arise from some blood-poison or constitutional degeneration.

Among the more common causes of this variety of paralysis may be mentioned hysteria and the poisons of certain diseases, as gout, rheumatism, syphilis, mineral poisons, as lead and opium, etc.

Rheumatic Paralysis.—In the partial but persistent paralysis that occasionally follows subacute muscular rheumatism, faradization has proved exceedingly efficacious. The muscles most frequently affected by rheumatic paralysis are the deltoid and trapezius (in consequence of which it becomes impossible or difficult to lift the arm from the side), the extensor muscles of the forearm, the muscles of the lower extremities, and occasionally the interossei and lumbricales muscles.

Electro-Diagnosis—Treatment.—The electro-muscular contractility in recent cases is normal; in long-standing cases, diminished. General as well as purely local treatment is frequently required in paralysis of a rheumatic origin, in order to combat the rheumatism in the constitution, as well as its local manifestations. The faradic current has, on the whole, proved of the most service in our hands in this disease, although both the galvanic and static electricity are useful.

In this, as in other forms of paralysis, atrophy of the muscular tissue occurs after a certain length of time. It is extremely important to begin treatment before the muscles become thus affected. In cases of rheumatic paralysis, where the invasion has been sudden and the pain considerable, electric excitation produces pain; but where the invasion has been more gradual and unattended by pain, electric excitation causes very little, if any sensation.

We have treated quite a number of cases of rheumatic paralysis of the deltoid, the trapezius, and of the lower extremities, and usually with the most satisfactory results. Electricity is always indicated in this condition, and few cases, doubtless, would fail to improve, even if they do not recover under its influence.

Syphilitic Paralysis.—Syphilitic nervous affections may exist either with or without appreciable structural change. Paralysis which results from secondary syphilis may derive benefit from electric treatment.

The principles and method of treatment are the same as for rheumatic paralysis. There is as yet no evidence that general faradization or central galvanization have any special influence over the syphilitic poison; they act as general tonics and thus help the system to contend with the disease.

Lead Paralysis.—In slow poisoning by lead the metal becomes diffused throughout the whole system, and exerts its influence, though in an unequal degree, on every nerve and organ.

As is well known, however, the upper extremities are most frequently affected by paralysis (more or less complete). The muscles usually affected are the extensors of the hands and fingers, so that they hang down by their own weight. It is probable that these muscles are chiefly affected in this disease, as in hemiplegia, because they are weaker and operate at a great mechanical disadvantage.

Electro-Diagnosis and Treatment.—The electro-muscular contractility of the affected part, in this form of paralysis, is always diminished; and frequently it is entirely lost, even in cases where there is little or no atrophy of the muscles. The electro-muscular sensibility is usually unimpaired. Diplegic contractions may appear in this disease. According to Hitzig, mobility in cases of lead poisoning is lost before electric contractility.

If the electro-muscular contractility is completely lost, it is better to apply a galvanic current (5 to 15 milliamperes) to the paralyzed part for a few minutes before the faradic is made use of. The latter current should be used daily, and not longer than ten or fifteen minutes at each sitting. As soon as the slightest contractions are produced by the faradic current, the galvanic may be discontinued. In some cases we have thought that the galvanic current answered better than the faradic, even when the muscles respond to the faradic.

Paralysis from Opium, Stramonium, Arsenic, etc.—In desperate cases of poisoning by opium, electricity has been repeatedly used with success. The method of artificial respiration may be used.

After recovering consciousness from severe poisoning by opium, or other poisons, the various limbs of the body are occasionally left in a permanently paralyzed condition that persistently resists all the efforts of nature and medicine. In two cases of this kind that have fallen under our observation and treatment, general faradization proved quickly and permanently beneficial.

Hysterical Paralysis.—The hysterical form of paralysis is constitutional, because the entire central nervous system is degenerated into a condition of abnormal susceptibility.

Electro-Diagnosis.—In this form of paralysis, the electro-muscular contractility in recent cases is unimpaired; in old cases it may be impaired or lost, or the electro-sensibility may be very much blunted. Diplegic contractions sometimes appear in hysteria. The loss of power is usually incomplete, and sooner or later recovery usually takes place.

Treatment.—The disease is constitutional and demands general as well as local treatment. In many instances general faradization promotes rapid recovery; other cases are very rebellious and only improve up to a certain point. The general treatment may be combined with central galvanization and faradization of the affected part. In some cases static electrification is superior to any other method of treatment.

Central Paralysis.—Central paralyses are those which depend on some special and distinct morbid condition of the brain, spinal cord, or sympathetic.

Hemiplegia and paraplegia, with their complications, are the more frequent and important manifestations of paralysis of central origin.

When the morbid process is in the central ganglia, the reaction may be either normal, or increased, or decreased.

When dizziness is excited by a very mild galvanic current, there is reason to suspect some morbid process within the brain. The diagnosis of the diseases of the brain with which hemiplegia is associated is much aided by the ophthalmoscope, which frequently reveals changes in the optic disk, the retina, the choroid, and the blood-vessels. Cerebral effusion may be indicated by congestion or infiltration of the optic disks on the side on which the clot exists; tumors of the brain by neuritis, neuro-retinitis, and ischæmia; softening occasionally by neuritis or atrophy.

Prognosis.—The prognosis of hemiplegia under treatment by electricity is in general much better than has been supposed. Manifestly, everything depends on the nature and seat of the affection as well as on the age and constitution of the patient.

The prognosis is better in proportion as the symptoms are uncomplicated; better in the young and middle-aged than in the old. Cases that are so thoroughly cured as to leave no marks behind are exceptional. The improvement, however rapidly it may progress at first, usually stops at some point short of a perfect cure. The majority of cases can be benefited, sometimes rapidly benefited, up to a certain point, after which the improvement cannot be pushed by any amount of treatment. It is furthermore always necessary to bear in mind the liability to other attacks; very many cases are improved at once and rapidly, while with others the progress is almost imperceptibly slow.

In psychic symptoms (melancholia, hypochondria, etc.), the prognosis is often quite favorable. A persistence of these psychic complications, even when other symptoms appear to yield, we have come to regard as an unfavorable sign.

In anæsthesia, when uncomplicated with other symptoms, the prognosis is remarkably good, even when variously complicated with paralysis of motion or disorder of the cranial nerves, and the anæsthesia may yield, even though its associated symptoms are not affected.

In severe disorders of speech the prognosis is not very favorable. They are, however, susceptible of treatment.

In impairment of nutrition—the muscular atrophy that so frequently accompanies hemiplegia—the prognosis, especially when the cases have not been too long neglected, is oftentimes exceedingly favorable. After the affected lower limbs have become much reduced, they may by persevering faradization and galvanization be restored to their normal size.

In contractions of muscles and convulsions, the prognosis is unfavorable.

In disorders of bladder and rectum, the prognosis is not very favorable.

In affections of the joints the prognosis is not very favorable.

In cases complicated with hysteria or hysterical symptoms the prognosis is better than in cases not so complicated. In very strong and vigorous persons of coarse organization the prognosis is generally not so good as in the nervous organization.

Other conditions being the same, the prognosis is much better for those cases where the arm is not affected; and when both the arm and leg are affected, the leg is susceptible of the earliest and greatest improvement. The chief difficulty in the hand is usually with the extensors and interossei, which, being very long and weak muscles, and acting as they do at the worst power of the lever, are the greatest sufferers in hemiplegia, and are very slow to resume their normal functions.

It should always be borne in mind that the tendency of the disease is toward recovery up to a certain extent, and that the improvement which takes place in the early stages, sometimes very rapidly, is due in great part to nature and time.

Electric Treatment.—Diseases of the brain of the different varieties are to be treated by both general and localized faradization according to the indications of each case. General faradization is frequently indicated in hemiplegia as in other manifestations of disease of the brain, on account of the general debility of the functions that accompanies and follows an attack of disease of the brain. It improves the general nutrition.

Central galvanization with a very mild current is a method of treatment that is of great service in these conditions. The special form and locality of the galvanization will depend on the supposed locality of the disease.

It is well to use central galvanization alternately with general or localized faradization.

There is little doubt that this method of treatment, when not overdone, acts beneficially on the nutrition of the brain, directly by the passage of the current through the brain, and indirectly through the modification of the cerebral circulation by the irritation of the sympathetic.

It must be confessed, however, that the exclusive use of central galvanization in cranial disorder is far from being satisfactory, and for these four reasons: First. With all our improved means of diagnosis it is impossible to fix with anything more than approximate certainty the seat or even the nature of the morbid process in diseases of the brain; hence, all localization of the galvanic current in this or that part of the head must at best be empirical and tentative. Secondly. It is impossible to localize the galvanic current entirely in any small portion of the brain. Thirdly. Diseases of the brain are usually accompanied and followed by general feebleness that demands constitutional treatment. And fourthly, the paralysis will not yield to merely central treatment directed to the seat of the disease, but must be treated itself. In hemiplegia also the spinal cord becomes affected through disease; hence the theoretical indication for galvanization of the spine, or, better still, the entire method of central galvanization.

General faradization, thoroughly used, affects all parts of the brain and the sympathetic at each application, if not directly at least reflexly, and in addition powerfully and beneficially affects the entire periphery. The improvement which is acquired by the extremities and by all the superficial muscles, and by the viscera especially, under general faradization, we believe, reacts favorably on the brain and aids the reparative process. Our best results thus far have been obtained by the combination of localized faradization of the paralyzed muscles, general faradization, and central galvanization.

In regard to the comparative merits of central galvanization, peripheral and general faradization, and localized galvanization of the nerve-centres, in hemiplegia, we should say decidedly that the latter method—localized galvanization of the brain, sympathetic, and spinal cord—is the least important. By itself alone, unaided by other methods, it will accomplish but a little. It comes in very well, however, to supplement other methods, and may be used in connection with them. The full method of central galvanization, however, by acting thoroughly on the whole central nervous system, accomplishes much in hemiplegia, and may carry on the improvement after peripheral and general faradization have finished their work and lost their efficacy.

Time of Beginning Treatment.—In regard to the time of beginning treatment after an attack of hemiplegia, each case must be studied by itself. As a rule, it is better to wait two or three weeks, until the active irritation in the brain has in a measure subsided. The almost universally entertained idea, that it is better in all cases to wait three, four, or six months, until the muscles have been long atrophied and contracted, and the shoulder-joint become perhaps permanently immovable, before beginning electric treatment, is a serious error. If proper caution be used, it is never necessary to injure the patient at any stage of the disease. Cases that are taken early may be treated at first by exclusively localized faradization; and afterwards, when that has accomplished all that it can and the patient ceases to progress, it may be well to resort to general faradization and central galvanization. Electrization of the facial muscles on the affected side sometimes materially aids the speech, but it may cause unpleasant symptoms, and in the early stages especially should be avoided. Mild galvanization may sometimes be used before faradization of the muscles.

Accessories to Electrical Treatment of Paralysis.—The treatment of paralysis of all kinds by electricity may be greatly aided by observing the following rules:

1. Thoroughly soak the part with warm water before beginning treatment. When this is done a much feebler current will produce contractions and the contractions will be more active, and some muscles will readily contract which otherwise would not contract at all.

The skin when dry is, as we have seen, a poor conductor, and in proportion as it becomes thoroughly moistened in that proportion does its conductivity increase.

2. Relax the muscles when the application is made. The advantage of the observance of this rule is decided.

In treating paralysis of the extensor muscles of the hand, for example, flex the hand backward a little and then relax the extensor muscles. In treating paralysis of the peronei muscles of the leg, raise the foot so as to relax these muscles and the tibialis anticus. The muscles of the thigh are most relaxed when the patient is sitting, and most tense when the patient stands. In treating paralysis of the face, draw back the muscles of the affected side towards the ear. Dr. C. E. Detmold has suggested the use of a blunt, curved wire. This wire is placed in the corner of the mouth and the other end is attached by an elastic to a curved wire behind the ear. This contrivance may be worn not only during treatment, but at night, if it be not too disagreeable, and an hour or so during the day.

For keeping the hand raised in lead paralysis, the late Dr. George Van Bibber, of Baltimore, devised a contrivance consisting of Sayre's artificial rubber muscle connected by eyelets to elastic bands attached by adhesive plaster to the arm above the elbow at one extremity, and at the other extremity to the hand and fingers.

Dr. Van Bibber utilized the same principle in the treatment of ptosis. In order to hold up the lid he applied a narrow bit of adhesive plaster to the forehead, and to the lid itself.

3. Enlist the mental co-operation of the patient in the treatment. Let him try to move the paralyzed muscles at the very moment that the current is applied. Concentration of will alone is sufficient to help paralysis, as has been proved by actual experiment.

4. Passive movements of the limbs at the joints, massage, and manipulation of individual muscles. The joints should be rotated so as to combat the tendency to stiffness, and the kneading of the muscles should be carefully and thoroughly performed; massage and passive movements are usually but half done.

5. Apply dry heat to the affected muscles before the electricity is applied, or at any time during the intervals. This can be done in various ways. A good way to bring a paralyzed arm or leg under the prolonged influence of dry heat is to take a common sewer-pipe as sold in the shops, of a suitable size and curvature, heat it through in an oven, cover it with cloths and let the limb remain in it until the heat is dissipated. In this way not only the forearm and leg, but the whole arm, including the shoulder-joint and the thigh with joint, an be daily subjected to the effect of the prolonged heat. This treatment not only temporarily increases the electro-muscular contractility of the paralyzed muscles, but permanently improves the nutrition both of the muscles and of the stiffened joints.

All the above suggestions will apply to the treatment of every form of paralysis.

Progressive Bulbar Paralysis. — Through the investigations of the pupils of Charcot and of Leyden it has been established that these symptoms depend on degeneration of the nuclei of the medulla. The distinctive features of this affection are paralysis of the muscles of the tongue, lips, soft palate, and also of the pharynx and larynx. There is difficulty both in speaking (especially in pronouncing certain letters) and swallowing. The saliva dribbles. Food is sometimes forced into the nostrils or larynx. In the last stage there is debility and difficulty of respiration.

Prognosis.—This disease is believed to be surely fatal in a few months. Faradization of the pharynx and tongue is, however, of essential service in occasionally relieving the difficulty in deglutition, and also some of the other symptoms.

Paralysis of Spinal Origin—Paraplegia.—The exact differential diagnosis of the various morbid conditions of the spinal cord that give rise to paraplegia is sometimes a matter of considerable difficulty, and for these two reasons:

1. All known morbid conditions of the cord have more or less symptoms in common. In order that any of them may be of special diagnostic value, it is necessary that they should be taken in connection with other symptoms.

2. Many of the morbid conditions of the cord are complicated with each other, and the symptoms must be correspondingly complex. Thus meningitis may exist with myelitis, and the term myelitis itself is a genus of which there are several species. It is difficult to draw the line where irritation ends and congestion begins, and equally difficult to determine at what stage a condition of hyperæmia or congestion becomes a condition of inflammation.

Electro-Diagnosis.—In the early stages of spinal paraplegia the galvanic and faradic reaction may be normal, but in the course of a few weeks or months becomes diminished. In most of the cases that consult the physician there is diminished or destroyed electro-muscular contractility.

Electro-muscular sensibility is usually more or less diminished. Electro-muscular contractility is usually much more diminished in the severe forms of paraplegia than in hemiplegia. In cases where the posterior columns are affected electro-anæsthesia may also exist.

Treatment.—In hemiplegia, as we have seen, the electric treatment is substantially the same whatever the nature or seat of the cerebral lesion. Similarly in paraplegia the treatment, so far as electricity is concerned, is the same, whatever be the nature of the spinal lesion on which the paraplegia depends. Spinal paraplegia should be treated by galvanization of the spine, and peripheral faradization or galvanization; to depend on one method solely is unnecessary. In paraplegia the electro-muscular contractility is frequently so much diminished that it is necessary to give particular attention to the motor points in order to produce contractions. Whether general faradization and central galvanization be employed will depend on the general condition of the patient. In the early or subacute stage the *séances* should be short; in the chronic stage the *séances* may sometimes be more protracted. In many incurable cases the general tonic effects of general faradization alone are of very great service.

Prognosis.—Very many cases of spinal paraplegia can be benefited by electric treatment, but very few can be entirely or permanently cured.

We may look for perfect recovery in some cases that are taken early, and in cases that depend on hysteria, congestion of the cord, or exhaustion. Cases of myelitis, meningitis, non-inflammatory softening, and the various forms of sclerosis are, as a rule, but little benefited, although they may sometimes improve a little up to a certain point.

Peripheral Paralysis.—A true peripheral paralysis manifestly excludes all lesions or influences of a central origin. The cause must be sought for in some portion of the nerve-tract after it has emerged from the bones that enclose the nervous centres.

The principal causes of peripheral paralysis are:

1. The action of cold on the superficial distribution of nerves.
2. External injuries.
3. Pressure on the nerve from morbid growths, etc.
4. Destruction of a nerve by carious bone, etc.

Facial Paralysis.—Facial paralysis is among the most important peripheral nervous diseases, and from experience in a large number of cases we can affirm that electric treatment very materially hastens the cure in many instances. The symptoms of facial paralysis vary not only as its cause is central or peripheral, but also according to the portion of the nerve affected. Paralysis of the seventh pair without coincident paralysis of an arm or leg seldom results from cerebral hemorrhage. It may occur, however, but it may be readily distinguished from the peripheral form of the affection. In complete facial paralysis of peripheral origin the orbicularis palpebrarum muscle is paralyzed, and the eye cannot be entirely closed; while if the cause is central this muscle is, as a rule, unaffected, and the eyelids can be brought together. In some exceptional cases a certain lesion may paralyze the orbicularis muscle, while occasionally, in peripheral facial paralysis, the nerves that supply the muscles of the eye may escape, thus leaving it free to close. The fact that in facial paralysis of central origin the electro-muscular contractility is unimpaired, while if the nerve itself is the seat of the injury the muscles refuse to respond to the faradic current, materially aids us in diagnosis. It is difficult to see how electricity can be of much service in cases of facial paralysis caused by a neuritis within the bony canal and the consequent swelling and compression of the nerve, but if only that portion of the nerve external to the Fallopian canal is affected the case is quite different. Gowers* insists that there is no evidence that cold ever paralyzes the intra-muscular nerves, and doubts whether inflammation ever affects the nerve after its emergence fromt he canal. Accepting this theory, it would be most difficult to account for some of the rapid recoveries that have taken place in cases that were apparently stationary, when submitted to proper treatment.

* "Diseases of the Nervous System," London.

Electro-Diagnosis.—In facial paralysis of a peripheral origin, the farado-muscular contractility is usually diminished or lost; galvano-muscular contractility may be increased or normal; though in some cases it may be diminished, it is rarely lost. Facial paralysis is one of the conditions in which the difference between the two currents, in their power of producing contractions of muscles, is typically shown. The galvano-muscular contractility sometimes becomes so much increased that when the farado-muscular contractility is entirely abolished the diseased muscles respond to a much feebler galvanic current than is necessary to produce contractions on the healthy side. As the muscles resume their normal condition under treatment, the galvano-muscular contractility diminishes.

Prognosis.—The prognosis of facial paralysis of a peripheral origin is generally very favorable. Since most of the cases are due to slight and temporary causes with the exception of those cases caused by permanent pressure or degeneration of the nerve, electric treatment is usually of much avail.

Treatment.—Facial paralysis should be treated by localized faradization and galvanization. When the muscles fail to respond to the faradic current it is of but little worth to use it; it is far better to depend on the galvanic current. In this disease the current-reverser electrode is exceedingly convenient. A current just sufficient to produce contraction of the muscles is better than stronger currents, and short applications are preferable to long ones.

Paralysis from Pressure and Cold.—Paralysis sometimes occurs from pressure on the nerves of the arm during sleep, and most frequently in persons who are intoxicated.

Paralysis of the arm may also arise from the pressure of a board or any other hard object under the arm. It may also be caused, like facial paralysis, by exposure to cold. Paralysis may also arise from the presence of the fœtus in parturition. All these forms of peripheral paralysis may be treated by electricity, preferably by the galvanic current, and with curative results, unless the nerve be too severely injured.

Reflex Paralysis.—Under this head are included those peripheral paralyses which arise by reflex action through the central nervous system, from some remote part of the body. Some of the cases of general paralysis of all the extremities are of this nature. While it is probably true, as Gowers asserts, that many if not most of the palsies termed reflex are in the majority of cases due to organic diseases, either primary in the cord or secondary to an ascending inflammation of nerves, yet it is undoubtedly true that certain disturbances of the central nervous system may occasion paralysis that continues long after the exciting morbid condition has disappeared.

Treatment.—Localized faradization or galvanization is required in this form of paralysis. This treatment should be directed not only to the paralyzed muscles, but also in some cases to the diseased part from which the paralysis is reflected. In doubtful cases, general faradization and central galvanization may be tried.

Prognosis.—This is much more favorable than in paralysis that directly proceeds from organic disease. Everything depends on the nature and locality of the irritation.

CHAPTER XIX.

LOCOMOTOR ATAXIA—POSTERIOR SPINAL SCLEROSIS.

In regard to posterior spinal sclerosis we have these remarks to offer:

1. The great exciting causes of the disease are exposure to wet and cold, mechanical injury, and syphilis. It is a fact not thoroughly appreciated by the profession or by the people that it is as possible to take cold in the cord as in the lungs. Cold in the cord manifests itself just as cold anywhere else manifests itself—that is, by congestion; and if the colds are repeated, the congestion becomes a fixed condition that is not easily resolved, and in time may go on to the condition known as posterior spinal sclerosis, or locomotor ataxia.

The connection between this structural lesion of the cord and exposure to wet and cold is not always directly apparent, is but rarely suspected by the patient, and almost never inquired into by the physician, partly because of its remoteness, and partly because the professional mind, at least, has been diverted in the direction of sexual excess as the one great cause of ataxia.

The mechanical injuries that most frequently give rise to sclerosis of the cord are severe blows and falls, or the shock of accidents of almost any kind. It is not necessary that the injury, whatever it may be, should be received on the spine or head, in order to cause symptoms of ataxia. A violent concussion from any injury that is directly felt on the arms or legs may have the same effect as a direct injury to the back.

2. The cord is predisposed to take cold by any causes that tend to exhaust it. Among the more prominent of these causes are long marching or violent and wearying muscular exertion of any kind, especially of the sort that draws heavily on the lower part of the cord, excessive intellectual exertion, and sexual excesses. The two latter predisposing causes, excessive intellectual exertion and sexual excesses, operate far less frequently than the purely physical causes.

3. In regard to the supposed influence of sexual excesses on this disease, the profession must revise its opinion. That sexual excesses constitute an important factor in the causation of nervous diseases must be admitted, but it is not structural so much as functional diseases that they excite.

One plausible reason for suspecting that sexual excess is the cause of ataxia is found in the unnatural sexual desire that so often precedes the ataxic symptoms. The increase of desire naturally calls the attention of the patient to the sexual organs, and almost compels a certain amount of abuse; and when questioned concerning his habits, it is no marvel that he recalls and confesses his recent experience in this respect. Now, this increase of sexual desire is often, if not always, the effect of spinal congestion, by which the cord is rendered excessively active; it is a sign, not of health, but of disease. It is not, however, nor is the abuse which it invites, the cause of the degeneration of the cord into which congestion leads.

The most, then, that can be said of sexual abuse in its relation to ataxia is that, by weakening the cord, it may in certain temperaments prepare the way for colds, mechanical injuries, or perhaps for syphilis, to enter in and take possession.

Syphilis is, indeed, far more important as a causative factor in the production of ataxia than any other cause, and perhaps than all other causes combined. Of our own cases, nearly fifty per cent. were distinctly syphilitic in origin.

4. It is more frequent, so far as we can learn, in the North than in the South; cold, damp climates favor its development. In the early stages, long residence in tropical or subtropical regions is worthy of trial.

5. It is very often complicated with congestion and sclerosis of the anterior column. The neuralgic pains, of which so much is said, do not appear in much more than half the cases. We are not yet able to say whether they are a good or a bad symptom. One thing is sure, the worst and most obstinate cases we have yet seen had no neuralgic pains. Another point equally true is, all the characteristic neuralgic pains may exist in those who never have ataxia.

Electro-Diagnosis.—The electro-muscular contractility, or at least irritability, may be normal or increased. This fact distinguishes locomotor ataxia from ordinary paralysis of motion depending on anterior or lateral spinal sclerosis, in which the electro-muscular contractility is usually diminished. The electro-muscular contractility may, however, be diminished in certain forms and stages of posterior spinal sclerosis, or when complicated, as it may be, with anterior spinal sclerosis, or with hysteria or general congestion of the cord, or of the membranes.

Prognosis.—The prognosis of this disease under electric treatment alone, or in combination with drugs, may be thus generally stated: A very small proportion of cases apparently recover. These cases are mostly of syphilitic origin, where specific treatment accomplishes more than electricity. A considerable number are decidedly benefited in all the leading symptoms; about the same number are but slightly benefited; and in a few cases absolutely nothing is accomplished.

The proportion of absolute cures is so small that there is a natural temptation to doubt the diagnosis or pathology of any reported cure, excepting in cases of specific origin. The cases that are brought on by mechanical injury, especially by concussion, offer the best prognosis; and this is true, we believe, of other nervous disorders. The explanation would appear to be that the disease excited by concussion is of a temporary and comparatively transient character, and the character of the lesion is far less severe than in those cases that come on slowly, through long years of incubation. In our observation the most satisfactory improvement has been in those cases of ataxia that were brought on by concussion. This is also true of paralysis in general, excepting, of course, those cases where the spinal cord is directly and seriously injured.

Most of the published statements in regard to the prognosis of the disease under electricity, as indeed under any other form of treatment, must be received with great caution. Many of the physicians who report the cases have perhaps never before seen a case where they made the diagnosis of ataxia, and in the instance that they publish there is much probability of deception; and this probability is increased if the patient perfectly and permanently recovers. Hysteria comes in to complicate the diagnosis, and some of the reported cures have been, without doubt, of an hysterical character. Spinal congestion is very often mistaken for spinal sclerosis; the symptoms run into each other, and the former in some cases leads to the latter. But spinal congestion is relievable and curable, while spinal sclerosis is rarely so. Some of the supposed cures have been very likely simply remissions in the course of the disease.

Treatment.—Ataxia may be treated electrically by a combination of several different methods of electric application: Galvanization of the spine, central galvanization, and general faradization when cerebral disturbance or general ataxia of the nervous system appear; galvanization of the cervical sympathetic, and peripheral faradization with sponges and the metallic brush. All these various applications may be made with weak or strong or medium currents, from five to fifty milliamperes, according to the wants of each case. Static electricity is a valuable palliative. Administered over the spine by means of long percussive sparks, we have known it to greatly alleviate some of the distressing symptoms of ataxia.

We have found good results from simply treating the leading symptoms—the anæsthesia—without any special reference to the cord. We do this by means of the metallic brush, or by a finely-pointed metallic electrode, making the application over the feet, legs, arms, and all parts of the body that are anæsthetic. The end justifies the means. We have found more good, in some cases, from this method than from galvanization of the spine and all the other methods combined. When the anæsthesia is profound and permanent, currents of great strength are sometimes not only not disagreeable, but positively agreeable.

In recommending this method we do not recommend exclusive reliance upon it; it is to be used in alternation with the other methods of which we have spoken. It should not be forgotten that the reflex effect of powerful peripheral faradization on the cord may be of greater service than galvanization of the spine. In connection with other methods, the suspension treatment may prove of essential service.

CHAPTER XX.

CHRONIC SPINAL MUSCULAR ATROPHY.

This disease is characterized by slow wasting of the muscles, and under its head are included progressive muscular atrophy, wasting palsy, amyotrophic lateral sclerosis, and chronic poliomyelitis. In all these conditions the muscular changes are referable to degeneration of the ganglion cells of the anterior cornua of the spinal cord.

In cases of chronic spinal muscular atrophy the electro-muscular contractility is either diminished or destroyed. Elcetro-muscular sensibility is usually diminished. Various changes in muscular irritability may take place during the progress of the disease.

Reflex contractions occur in muscular atrophy. Diplegic contractions also appear in this disease. These facts, taken in connection with the history of the case, the atrophy, the fibrillary contractions, swellings, and anchylosis in the bones and joints, the anæsthesia, and the neuralgia, make up the diagnosis. Diplegic contractions were first observed in muscular atrophy by Remak; they have since been observed in hysteria and other irritable conditions.

The disease does not always exist alone; it may be complicated with locomotor ataxia, with paralysis of the cranial nerves, and other disorders of the brain.

Prognosis and Treatment.—Our better and increasing knowledge of the possibilities of electro-therapeutics fortunately enables us to modify to some extent the prognosis in this disease. That the prognosis is grave cannot be denied, but by persistently following out the treatment that of late years has proved so successful, we confidently assert that not only may the disease be arrested far more frequently than in the past, but that in not a few instances the nutrition may be so far improved as to amount to approximate recovery.

In no other forms of disease does it seem to us so important that especial emphasis should be laid on the electric treatment as in those of the so-called progressive character. In many of the phases of paralysis, in the neuralgias, and in most forms of local and constitutional disturbance where the indications call for electricity, other remedies as well have their uses, and in many instances are even of greater service.

When we advance, however, to the consideration of those ominously progressive disorders, ataxia and muscular atrophy, we recognize the fact that, with the exception of those cases which depend on a syphilitic taint, our ordinary remedies exercise but little control over their progress. We have therefore almost in despair turned to the therapeutics of electricity in these diseases, and although it has failed by far to accomplish all that could be desired, it has yet proved to be more efficacious than is generally credited. In some cases it certainly arrests the disease.

As a rule we alternately make use of central galvanization in its most thorough form with faradization and galvanization of the affected muscles. Whether the alternating sinusoidal current would accomplish more than these methods, or as much, we are not prepared to say. Both this form of electricity and the franklinic possess powerful nutritional properties, but the latter certainly has in our experience failed to afford the same relief as the dynamic forms of electricity.

Persistent faradization of individual muscles has been recommended by Duchenne,* and among others who have reported recoveries by this simple and single method might be mentioned Dr. Alex. P. Fiddian.

The case † that he details was treated by that form of electricity generated by the old-fashioned magneto-electric machine, and although the authenticity of the statements cannot be doubted, yet a knowledge of the combined experience of those who have accomplished most in electro-therapeutics must confirm us in the assertion that in order to achieve the best results, both currents must be used and the applications directed to the nerve-centres as well as to the affected muscles.

Poliomyeletis (*Subacute and Chronic*).—An important distinction between this disease and the preceding is that in poliomyelitis, whether occurring in the adult or child, the paralysis precedes the wasting—the loss of power as a rule first appearing in the legs. Faradic irritability soon becomes lost, with temporary increase of galvanic irritability and degenerative reactions. In consequence of the nerve-fibres being unequally affected, we sometimes get the mixed form of degenerative reaction—galvanic irritability increased in the muscles with retention of faradic irritability in the nerve.

Except in traumatic cases the prognosis is always grave, and yet active and persistent treatment is capable of doing much in many of these cases.

Poliomyelitis as it occurs in children—the so-called infantile paralysis—is more interesting and important than the same disease in the adult, because more frequent. The symptoms of the disease are very much the same as those in the adult—paralysis of motion, with loss of electro-muscular contractility, some anæsthesia, great diminution of temperature, and muscular atrophy.

* "De l'Electrisation Localisée," p. 702.

† Med. Times and Gazette, July 20th, 1872, p. 66.

Duchenne, with the aid of the microscope, has investigated the condition of the muscles in muscular atrophy. For this purpose a trocar is necessary. Duchenne's trocar (Fig. 122) is introduced into the muscle

FIG. 122.—Duchenne's Trocar.

FIG. 123.—Noeggerath's Trocar.

open. When *in situ*, a piece of sharp steel is pushed, by means of a button, against the barb of the trocar. A piece of muscle is thus caught which, on the withdrawal of the trocar, can be examined.

Microscopic Examination of Muscles.—Noeggerath's instrument (Fig. 123) is introduced as a simple trocar, and when *in situ*, the wire contained in it, being pushed forward, causes the prongs or clasps on its extremity to emerge a little separated. When the wire is pulled out the prongs come together, bringing with them a piece of the flesh.

We present the cuts of Duchenne, with condensed explanations.

Normal fibre. ——First degree.——

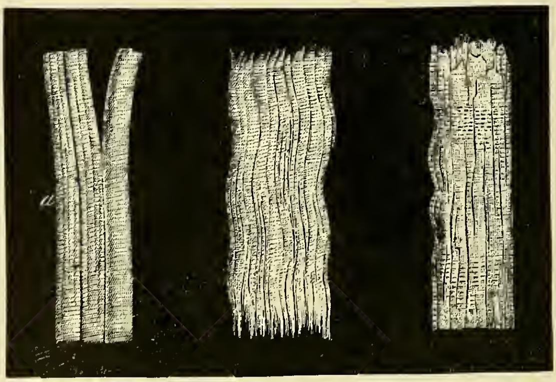

FIG. 124. FIG. 125. FIG. 126.

FIG. 124 "represents the normal fibres, with the transverse striæ."

FIGS. 125, 126.—"The transverse striæ are less distinct; they are frequently broken; the longitudinal fibres are more and more marked."

Second degree. Third degree.

FIG. 127. FIG. 128.

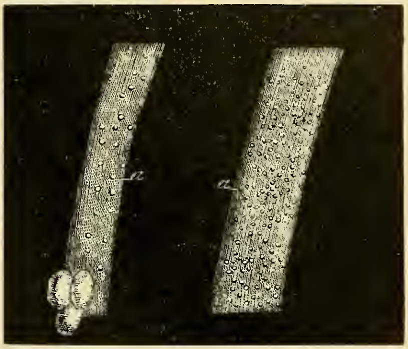

FIG. 129. FIG. 130.

FIG. 127.—"The muscular fascia is composed entirely of longitudinal fibres, the transverse striæ having completely disappeared."

"By the side of the muscular fibre adipose tissue is observed, composed of cells that are either (*a*) round or longitudinal; there are little drops (*b*) of fat deposited in the muscular fibre."

FIG. 128.—"The muscular fibres have still preserved their contractility, and are undulating."

FIGS. 129, 130.—"The longitudinal fibres have become less distinct. The molecules of fat are more and more abundant—again cover the figure almost entirely."

Fourth degree.

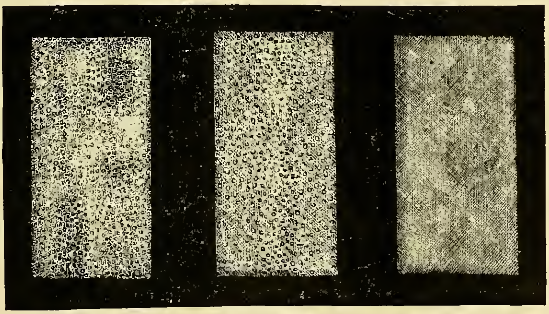

FIG. 131. FIG. 132. FIG. 133.

FIG. 131.—"The longitudinal fibres have disappeared. We see only fatty molecules very close together and little distinct, especially toward the axis of the fascia."

FIG. 132.—"The fat becomes more abundant and difficult; the muscular fascia is more transparent."

FIG. 133.—"Distinct molecules of fat are no longer perceptible; the fascia is composed of a shapeless mass.

"Each degree of fatty transformation corresponds to a degree of decoloration of muscular fibre."

Electro-Diagnosis.—In infantile paralysis there is diminution or utter loss of electro-muscular contractility. In patients so young the condition of the electro-muscular sensibility cannot of course be ascertained. The tactile sensibility is in some cases much diminished; in other cases it does not appear to be affected.

A slight degree of anæsthesia cannot be ascertained in very young patients. In this disease especially both currents are necessary in the diagnosis as well as in the treatment, and careful regard must be given to the "motor point."

In making an examination of the condition of the muscles of infants it should be remembered that, on account of their flabby character and the relatively large proportion of adipose tissue by which they are surrounded, they do not respond as readily nor as perceptibly to electrization as the muscles of adults.

Treatment.—Galvanization of the affected limbs is the method of electrization that is principally indicated in infantile paralysis. In those cases that fail to respond to the faradic current, the galvanic is indispensable. When the muscles have regained their contractility under the faradic current, faradization may be used either alone or alternately with galvanization.

Children will bear as powerful currents and as protracted localized applications, without apparent injury, as adults. No stronger currents should be used, however, than are just sufficient to produce full muscular contractions. The most frequent mistake is to overdo the treatment—to use too strong currents, and too long applications, and thus weaken rather than strengthen the muscles.

Galvanization of the spine is also indicated, and in connection with the peripheral treatment should not be neglected.

In infantile paralysis the general health is not necessarily impaired. Those cases that are accompanied with general weakness should be treated by general as well as localized faradization and central galvanization. Treatment by electrization is greatly aided by passive movements systematically and skilfully used, shampooing, frictions, and the application of dry heat and hot water to the affected limbs. (See remarks on Accessory Treatment under Hemiplegia.)

Prognosis.—The prognosis must depend on the cause, the probable nature of the lesion, the length of time that the disease has existed, and the condition of the muscles, especially as ascertained by electric and microscopic examination. If fatty degeneration is much advanced the prognosis is necessarily very grave.

Cases of a reflex or functional character may recover speedily without special treatment. Cases of organic character, which constitute the majority, and which have gone on to atrophy and degeneration, too often resist every method of treatment. It is rarely indeed that parents or guardians have the patience or the means to persevere and obtain the full benefit of which electrization is capable.

Frequently the improvement rapidly advances to a certain grade and then halts, or advances so imperceptibly as to discourage the parent.

Lewis Jones,* of London, who has reported a large number of cases of this character, formulated conclusions similar to our own, which are, that even in absolute and chronic paralysis, with loss of electric response to either current, cases of infantile paralysis should not be hastily abandoned to their fate. Such cases are not infrequently benefited by persistent treatment.

Idiopathic Muscular Atrophy (*Pseudo-Hypertrophic Muscular Paralysis*).—This disease is primarily muscular, but its clinical resemblance to spinal muscular atrophy is so great that it may properly be noticed in this connection. It manifests itself, as a rule, in late childhood, and was first described by Dr. Edward Meryon, in a paper read before the Royal Medical and Chirurgical Society, December, 1851. A case was subsequently reported by Dr. T. King Chambers, in the Medico-Chirurgical Transactions, 1854. The disease has been observed in two, three, and four children of one family. The disease has been systematically studied by Duchenne, who was the first to set it before the profession as a distinct disease. The symptoms of this affection in the first stage are weakness in the lower limbs and flexion of the toes; in the second stage, increase in size of the muscles of the legs—especially of the calves, of the back, and of the gluteal muscles; in the third stage, extension of the disease, muscular atrophy, exhaustion, and death.

Electro-Diagnosis.—Farado-muscular contractility usually diminished; galvano-muscular contractility may be either normal or exaggerated; electro-muscular sensibility is sometimes diminished, sometimes normal.

Prognosis.—The prognosis is always uncertain, at least as to the course and duration of the disease. While many are sure to die within a few years, others live on for many years and die of intercurrent affections.

Treatment.—Whatever benefit may be derived from electric treatment must come from its influence over nutrition, and therefore not only should faradization and galvanization of the affected muscles be attempted, but the constitutional methods of treatment of general faradization, central galvanizaton, and static electrification.

* British Medical Journal, March 10th, 1894. Universal Medical Journal, April, 1895.

CHAPTER XXI.

RHEUMATISM AND GOUT.

Rheumatism is a disease for which electricity, by various methods of application, has been employed, with more or less success, from the early periods of the history of electro-therapeutics. Next to paralysis, it is perhaps the disease in which the original experiments of electro-therapeutists were most frequently conducted; and for the reason that (like paralysis) it is so frequently obstinate to ordinary remedies.

Treatment.—Being a constitutional disease, it demands constitutional treatment. The best results are obtained by general faradization, combined with faradization or galvanization of the affected joints. In the deep-seated continuous pain of lumbago and muscular rheumatism generally, the surface stimulation of static electricity is often more beneficial than any of the dynamic forms of electricity. To confine the treatment to the affected joint is unphilosophical, and usually more or less unsatisfactory, for the obvious reason that it attacks merely a local symptom, which at any time may be transferred to other and remote parts of the body. The true method is to lay the axe at the root of the tree by making the applications general, so as to bring the whole system under the influence of the current. This treatment sometimes causes increase of the flow of urine, and almost always more or less exhilaration, and relief of the pain. Special attention should be given to the parts which are chiefly affected, and the swollen joints should be treated by mild and steady faradization or galvanization. Where in the acute or subacute forms the immediate effects are agreeable, it is probable that continued treatment will be of service. For the local treatment the galvanic and faradic current may be used alternately.

The effect of the current on the inflamed joints is to relieve the pain, reduce the inflammation, and, where effusion has taken place, to cause absorption. Absorption may be caused by both currents, in some cases more powerfully by the galvanic. If the currents are used too strong or too long, the pain and inflammation may be increased. For applications to very sensitive and painful joints, the positive pole is preferable. For rheumatic callosities and anchylosis, very prolonged local applications of the galvanic current may be tried.

Prognosis.—In presenting the prognosis of rheumatism great stress must be laid on the distinction between the chronic, subacute, and muscular varieties.

During our earlier investigations in electro-therapeutics we treated perhaps as many cases of rheumatism as of any one class of disease. The apparent results of treatment by electrization in many cases of muscular, and in a number of cases of the acute, subacute, and chronic varieties of articular rheumatism, excited our enthusiasm, and led us to hope that a remedy had been found that would prove very generally and powerfully remedial in all forms of this disease. Further experience and investigation compel us to declare that we are not to expect such rapid and decided benefit from electrization in the worst cases of chronic articular rheumatism as we at first supposed.

The most uniform results are obtained in the muscular form; the next best are the subacute articular variety, and the least satisfactory of all in the chronic stages.

A good opportunity to note the immediate effect of electrization is afforded in those cases where the disease is of such severity as to render any of the muscles of the body almost if not quite powerless.

Myalgia (*Muscular Rheumatism*).—This name is commonly applied to neuralgic or rheumatic pain of the muscles on movement, caused usually by exposure to cold or dampness. It may be distinguished from ordinary neuralgia—first, by the fact that the pain occurs chiefly on movement and not on rest, and, secondly, by the fact that the soreness is diffused through or over the muscles, and not seated or fixed in certain nerve tracts. It receives different names according to its locality. In the back it is called lumbago; in the thoracic muscles, pleurodynia; in the neck it simulates torticollis or wry-neck so closely as oftentimes to be confounded with that affection (see Torticollis).

Treatment.—Local faradization with a mild current, either stable or labile, usually relieves such cases in a short time. Stable galvanization also with a mild current may be at once effective. Severe applications may increase the pain in this affection. The fact that the patient is not at once relieved, or is worse after the first application, should not discourage us, since the final result may be satisfactory. Of the large number of cases that we have treated, nearly all have been relieved by a few applications. Static electricity by means of the roller electrode or general franklinization is especially effective in these cases.

Gout.—Gout is a disease which in the majority of instances is so thoroughly dependent upon errors of food and drink, and exercise and the influences of heredity, that its prevention and cure depend for the most part on the observances of strict hygienic methods. It is within the experience of every physician that hereditary influences are alone sufficient in many cases to cause attacks of gout. The victim may be most abstemious in eating and drinking and active in exercise, yet suffer at intervals from the characteristic pain and swelling of the smaller joints, clearly indicating the lithic acid diathesis.

Acute attacks of gout, therefore, depending upon errors of food and drink, combined with indolent habits, offer no encouraging field for the beneficial effects of electricity. It is indeed doubtful whether it would ever prove of sufficient service during the attacks in these ordinary cases to be worth the time and labor necessary.

Taking into consideration the catalytic and absorptive power of the galvanic current, it has been suggested that much could be accomplished through its use in dissipating the gouty concretions that form in the various joints of the body. Experience has not, however, confirmed the correctness of this suggestion. The deposits of urate of sodium resist with great persistency all external and mechanical methods of treatment, as well as the internal administration of remedies.

We have in past years treated many cases of this character, but we are bound to say that we have never yet seen a true calcareous deposit in the joints appreciably diminished by any form of electric treatment. We have, however, known of actual damage being inflicted by a too confident and careless resort to the galvanic current.

Rheumatic Gout (*Arthritis nodosa*).—This affection is neither gout nor rheumatism, but appears to be a distinct constitutional affection. It occurs most frequently in the delicate and the nervous, and may be regarded as essentially a condition of debility. It is very apt to affect the hands, fingers, and toes, and sometimes thoroughly cripples the patient.

Treatment.—This condition is most successfully combated by tonics, and electrization, more for its tonic effects on the system than for any special catalytic power over the enlarged joints. General faradization, central galvanization, and perhaps the static spark are the methods that experience has shown to be most useful in this very intractable malady.

Prognosis.—The prognosis for radical relief in rheumatic gout is not encouraging. The pains can be relieved, the sleep can be improved, and the system can be in every way strengthened by the electric treatment, and even the enlarged joints can be made to diminish in size, or at least to be less troublesome. As nearly all patients afflicted with rheumatic gout are in a condition of debility, the improvement experienced at first under general faradization is such as to lead them to hope for a permanent eradication of the disease. In this respect they are always disappointed. The disease may be held at bay, but is never banished. It is doubtful, indeed, whether the benefit is not entirely due to the tonic effects of the treatment on the system, and not at all to any special influence over the rheumatic gout.

Other remedies are so powerless in this affection that electrization is worthy of a trial for the sake of its general effects. We have treated a number of cases by general faradization, central galvanization, and local galvanization of the affected joints, with palliative and tonic effects of a most decided character.

CHAPTER XXII.

SPASMODIC DISEASES.

Of spasmodic diseases, this general law holds, that when recent, even though violent, they often yield to electric treatment, but when long standing, although easily palliated, they are seldom cured and are prone to relapse.

Chorea.—In the light of our personal experience in the treatment of chorea, the opinion expressed more than a quarter of a century ago by a distinguished physician is of much interest. "Electricity," he says, "is another agent which requires a passing mention in this place, though all that can be said respecting it is, that as yet there appears to be little or no reason for placing any confidence in it as a means of treatment. Whether this will always be the case, whether there are not modes of using electricity which will have the effect of quieting choreic and analogous movements, remains to be seen. I suspect that there are such modes, and that they will be beneficial, but I have not yet the facts to justify the expression of a belief on the subject." *

Electricity benefits chorea on the same principle that it benefits neurasthenia or hysteria and many other functional nervous diseases, because of that indirect improvement in nervous force which is a part and a result of the general improvement of nutrition. While electricity is neither life nor nerve force, it aids in sustaining both life and nerve force, as do light and heat; not by direct transformation, but indirectly through its influence over nutrition. This influence over nutrition, together with musculo-sedative effects, are brought about in greater or less degree by various methods of electrization, by general faradization, especially with the high-tension coil, central galvanization, static electrification, and even by peripheral galvanization. To obtain temporary musculo-sedative effects, there is no method that equals the depolarizing method of central and peripheral galvanization, by which is meant the elimination of either one or the other pole. In this way the neutral point is thrown outside the body, and the part or parts brought under the influence of either the negative or positive pole alone as desired. Static electricity (positive) is also sometimes useful in chorea in calming nervous excitement and as an aid to nutrition.

* C. B. Radcliff, M.D., F.R.C.P.: "On Chorea," 1868.

But the two methods that we have found, on the whole, to be the most effective in the treatment of chorea are central galvanization and general faradization. These two methods properly differentiated and used either alone or in alternation, according to the indications in each individual case, are capable of doing much, not only in alleviating the violence of the choreic movements, but in shortening the duration of the disease.

A somewhat useful point in the way of differential indication for the use of the two currents and the two methods of application, which has been forced upon us by repeated observation, is the following: For children of full habits and in that excellent condition of general health which we not infrequently see among the victims of chorea, the galvanic current is to be preferred. For those, on the contrary, who are weak and anæmic, with impaired nutrition, the faradic current or static electricity is far more grateful, and is followed by better results, both immediate and permanent.

Prognosis.—In regard to the prognosis of chorea under electric treatment there has been considerable skepticism, even among those who are friendly to electro-therapeutics. This skepticism has been due to the fact that the majority of cases of chorea recover spontaneously in time, and because their improvement under electricity is, in some cases, quite slow.

Aside from the well-known fact that many cases recover spontaneously in the course of a few weeks or months, direct and positive results of treatment can be appreciated in this disease more uniformly than in any other spastic condition. Cases of failure after protracted treatment by electricity are exceptional. The worst cases, when recent, sometimes seem to yield better than those which are comparatively mild.

Partial chorea, affecting the eyelid, the muscles of the neck, or a single limb, or group of muscles, is more obstinate than a much worse form of general chorea. The explanation of this inconsistency is that patients affected with partial chorea are apt to delay weeks, months, and years before taking treatment. Recent cases we have found to yield almost uniformly. All long-standing choreic cases need to be treated perseveringly—from one to several months being usually necessary to complete a cure. In some cases no apparent improvement takes place at the outset of electric treatment, and the friends of the patient become discouraged; but if the treatment be continued, a permanent cure may be obtained. Symptomatic chorea—dependent on cerebral or cerebellar disease—offers an unfavorable prognosis.

Children bear larger doses of electricity proportionately than adults. Central galvanization with a current strength of five to ten milliamperes to a child of ten, provided the electrodes are of sufficient size and well adjusted, is easily borne, and it is not unusual for us to increase the strength even to twenty milliamperes and more.

Writer's Cramp.—This affection is not peculiar to writers. An analogous condition may attack seamstresses, milk-maids, and others whose callings compel them to use for a long time a certain set of the muscles of the hand. It is believed that the affection is not purely peripheral, but that it frequently, if not always, is connected with disease of the upper portion of the spinal cord.

Whether found in the artist, rendering him unable to manipulate his brush—the pianist, preventing him from fingering his instrument—or the penman, causing his writing to be almost if not quite illegible—the same general characteristic is observed, viz., the recurrence of spasm or pain whenever an attempt is made to execute a special movement.

Pains resembling neuralgia or rheumatism so closely as to be confounded with those diseases, frequently accompany writer's cramp.

The *prognosis* in the early stages is sometimes favorable for a perfect cure; advanced stages of long-standing cases are usually rebellious; but even these may be much relieved. Rest from the occupation is almost imperative.

The *treatment* should be both central and peripheral. Galvanization of the upper portion of the cord and of the median and radial nerves, spinal cord, plexus, and nerve-currents, and faradization of the affected muscles and of their antagonists, may be tried, and when anæsthesia exists the wire brush.

Unfortunately, however, those who are most frequently subject to writer's cramp are the very ones who are unable to take the necessary rest.

Although the results of treatment by electrization in this variety of palsy is by no means uniform, yet it has undoubtedly been followed in many instances by approximate and even perfect recovery.

Torticollis (*Wry-neck*).—This familiar disease consists in a spasm of the muscles of the neck, by which the head is drawn to one side. The spasms may be tonic or clonic.

Although the pathology of the disease is obscure, it is yet quite clear that it is of a nervous character. More than by any other cause, it is brought on by excessive mental labor or anxiety. The symptoms usually come on gradually; the muscles of the neck on the side toward which the neck is turned are sometimes flabby and atrophied, and the muscles on the other side are hard, lumpy, and enlarged. Frequently the deeper muscles of the neck are involved, as well as the sterno-cleido-mastoid and trapezius. The spinal accessory nerve would appear to be at fault. The condition is really a kind of "partial chorea," analogous to writer's cramp, facial spasms, spasm of the eyelid, and, like all these, is usually very obstinate, except in the mild form and early stages.

Diagnosis.—The disease should not be confounded with common stiff-neck that is caused by rheumatism of the muscles of the neck and is analogous to lumbago. In stiff-neck, which usually yields to faradization like other forms of myalgia, the head is kept from moving by the pain which movement causes. Diseases of spine and diseases of the brain sometimes produce tonic spasms of the muscles of the neck that resemble torticollis.

Electric Examination.—On the affected side * the muscles sometimes exhibit increased electro-muscular contractility and sensibility. On the other side the electro-muscular contractility is sometimes diminished.

Treatment.—Galvanization of the muscles of the affected side with currents of from 5 to 15 milliamperes, and faradization of the muscles of the other side, galvanization of the sympathetic and cervical spine are the methods that should be tried in this disease. They may be tried simultaneously or in succession.

Protracted applications are not ordinarily indicated in this affection. General treatment is only required when the patient is debilitated.

In connection with the use of electricity, the hypodermic injection of morphine and counter-irritation of the cervical spine by blisters, and mechanical contrivances for keeping the head in position, may be tried.

Prognosis.—In the early stages torticollis may be relieved or cured by electric treatment alone. After it has been established for a number of months, it becomes one of the most intractable of diseases. Even when relieved by treatment, it is much disposed to relapse. No case should be abandoned until both galvanic and faradic treatment has been thoroughly tried, since it is the only method of treatment that offers much hope; and the physician should not be discouraged if the symptoms appear to be aggravated by the first few applications, but should reduce the strength of the current and the length of the *séances*. The same remark will apply to analogous diseases, such as writer's cramp and facial spasm.

Paralysis Agitans (*Shaking Palsy*).—There are two kinds of shaking palsy:

1st. Those with organic lesions.

Sclerosis of some form is the pathologic state that usually gives rise to the symptoms of shaking palsy.

2d. Those where no lesion can be discovered.

These are usually styled functional, although, like hysteria or chorea, they may be supposed to depend on some molecular derangements which are not revealed to the microscope.

The disease may be local or general; it may attack one limb, or the lower jaw, or all four extremities. It is most frequent in the aged, but is sometimes observed in middle life, or in the young.

Treatment.—Central galvanization and general faradization, for general effects, may be used in shaking palsy with benefit. The best results have been obtained by galvanization of the spine and sympathetic and

* It should be considered that the sterno-cleido-mastoid, as it pulls the back of the head toward the shoulder, turns the face in an opposite direction. The face therefore is turned away from the affected muscle.

brain, although Charcot and Reynolds before him advocated the use of static electricity and reported favorable results. Notwithstanding the adverse opinion of Gowers and the conclusions of Berger, who after treating twenty cases reported that not one received improvement, our own experience has been that electricity, if properly and persistently used, is capable in occasional instances of favorably modifying the course of the disease.

Prognosis.—Cases where all the limbs are affected are never cured by any method of treatment, especially in the aged. Cases in which only one limb, or one upper and one lower limb, are affected are sometimes benefited, and in rare instances cured. Temporary relief can sometimes be obtained where no permanent benefit results. The tremor of the limb is sometimes abated or completely arrested for one or more hours after the application either of general faradization or galvanization of the spine, and in rare cases entire recovery occurs.

Subsequently the symptoms return and are again relieved by the same methods of treatment, but the relief is of shorter duration than before. Gradually the tremor increases and resists all further efforts.

Asthma.—Asthma is one of the conditions for which it would be supposed, *a priori*, that electrization might be of service; and yet the published records of successful treatment are not very extensive. One of the earliest, if not the very earliest, experimenters in this department was Dr. Wilson Philip, who began his researches in electricity in the early part of this century. "By transmitting its influence (galvanism) from the nape of the neck to the pit of the stomach, he gave decided relief in every one of twenty-two cases, of which four were in private practice, and eighteen in the Worcester Infirmary. The power employed varied from ten to twenty-five pairs." The treatment which is theoretically indicated is galvanization of the pneumogastric and sympathetic. Benedikt mentions a case successfully treated by this method.

The methods we employ in asthma are galvanization of the pneumogastric and central galvanization, with occasional temporary but not permanent benefit.

The faradic current is sometimes effective in affording temporary relief after failure of the constant current. In several cases that have fallen under our observation persistent faradization of the chest and neck has been followed by marked relief.

Muscular Contractions.—These may arise in hysteria, in myelitis, meningitis, and spondylitis, diseases of the cerebrum and cerebellum, or they may be of a reflex character. They exist sometimes in neuritis or rheumatism.

The *treatment* consists in peripheral galvanization or faradization of the affected muscles or of their antagonists, with stable currents and galvanization of the head, spine, and sympathetic, according to the special indications.

The *prognosis* is usually unfavorable for all except the rheumatic cases.

Facial Spasm.—This affection, which is not unfrequent, is usually very obstinate against all treatment. The treatment is galvanization with the spinal-cord-muscle or nerve-muscle current. Recent cases may be cured by the application of the galvanic current to the branches of the fifth pair. Long-standing cases may be temporarily relieved, but are rarely permanently cured. Remak reported success even after the condition was very chronic.

Dysphagia from Spasms of the Pharynx.—This symptom though sometimes the result of organic central disease, is not unfrequently of a purely spasmodic character, and as such is amenable to electric treatment, either by external or internal applications. The method we adopt for such cases is to place one pole on the back of the neck and the other just above the sternum, or by the inner border of the sterno-cleido-mastoid muscle. If this method fails, internal applications may be made, by means of a catheter-shaped electrode, against the constrictors of the pharynx. Some cases yield with surprising readiness to external treatment. Cases dependent on central disease are usually quite rebellious.

A case of this kind, in which the food was returned through the mouth or nose, was cured by Hiffelsheim by galvanization.

The same authority has recorded a case of excessive and obstinate vomiting that was cured by five applications of the galvanic current to the pneumogastric.

Singultus (*Hiccough*).—This symptom, when it becomes permanently annoying, may be treated by galvanization of the sympathetic and pneumogastric. We have treated in this way two very obstinate cases without benefit.

Tetanus.—Mendel reported two cases of tetanus successfully treated by the galvanic current. He used various methods of application, central and peripheral. Immediate relief followed each application.

The conclusions at which he arrives from his cases are that a mild current should be applied to the affected muscles, without regard to the direction, although the positive pole should be applied to the antagonists.

Hydrophobia.—The disease is so rare in its occurrence, and so rapid in its course, that electric treatment, even by its most imperfect methods, has had almost no chance to be tested. The suggestions that we have to offer are therefore of necessity based on theory and analogy, and experience in the treatment of other and more or less allied diseases.

The best method of using electricity in a case of real or simulated hydrophobia would be to place the negative pole of the galvanic current at the pit of the stomach, and apply the positive successively at the top of the head, the nape of the neck (central galvanization), over the region of the pneumogastric, and down the spine. If the galvanic current cannot be obtained, the faradic (electro-magnetic) might be tried, although it would probably be less efficacious. Mild or moderate currents would be likely to do more good than very powerful currents, and there should be intermissions in the treatment. During these intermissions ice-bags might be applied to the spine. We should not expect that this treatment would cure real hydrophobia, but, if faithfully used, it would greatly relieve the horrible agonies of the disease, and, either alone or in connection with other treatment, would be likely to prolong life. Electricity has never yet had a fair trial in hydrophobia. Schivardi, who kept one of his patients alive several days, used only a partial and imperfect method, and no other treatment, so far as is known, has been so successful.

Hydrophobia is one of the very few diseases in which it is better to use electricity blindly and imperfectly than not to use it at all.

Stammering.—Dr. Althaus succeeded in curing a case of stammering of five years' standing, in a lad nine years of age, by the application of the galvanic current to the laryngeal nerves. The applications were made twice a week for two months.

Epilepsy.—In some most excellent remarks * made long ago on the treatment of epilepsy, Dr. Meredith Clymer stated that he had never heard of a permanent cure of the disease under the use of the bromides, either alone or in combination; and so careful and experienced an observer as Dr. J. Hughes Bennett declares that he has no personal statistical evidence to offer in proof of the curability of epilepsy by the bromides. In the absence of positive proof that prolonged use of the bromides may thoroughly eradicate the disease, the most cheering observation he has to make is that it is entirely possible that such may be the case. While we may regard the first of these statements at least as extreme, the suggestion that the best results will follow only when we call to our aid every measure that will tend to develop vital power generally commends itself to all. It is not alone, therefore, on the theory of a special influence on the nerve-centres or over the cerebral circulation that we employ electricity as an adjunct to the bromides, but also because of its undoubted powerful constitutional effects. Above all, it is a tonic, and yet its therapeutic range is wide enough to include both stimulating an sedative effects. We cannot but regard as both interesting and suggestive certain observations concerning the similarity of effect between the bromides and central galvanization and general faradization. Accepting the theory that a state of cerebral anæmia predisposes to sleep, it is not very difficult to believe that the feeling of drowsiness that so often follows central galvanization, and even general faradization, when specially directed to the cervical ganglion, is due to the influence of the current on the vaso-motor nerves.

In some cases sound sleep has for a few moments been induced with

* New York Medical Record, vol. xlv., No. 16.

the subject in an upright position while receiving the current through the brain. We recall several instances where, under treatment by central galvanization, patients were repeatedly put to sleep within a minute after the beginning of the application.

Theoretically speaking, there are indications for the use of electricity in epilepsy other than its general tonic influence, or its effects upon the circulation.

Idiopathic epilepsy consists, undoubtedly, in an increased excitability of certain portions of the cerebro-spinal centres.

It may be supposed that the nutrition of certain nerve-cells becomes altered, but this change is, in all probability, dynamic rather than physical, and therefore the microscope would be as useless in detecting differences between normal cells and those possessing excessive reflex excitability as it would be to demonstrate the difference between the native steel and the powerful magnet. An important indication, then, for the use of electricity in epilepsy is this very superexcitability of nerve-cells. We know that the galvanic current directly affects the brain. We fully appreciate its anelectrotonic effect upon peripheral nerves, and must be ready to admit the possibility of its affecting in the same way the nerve-centres. These theoretical considerations we have, so far as possible, endeavored to submit to practical tests, and we are quite convinced that this abnormal superexcitability that is so characteristic of epilepsy is in some cases held in check by the action of the galvanic current as readily as by the bromides themselves.

In several cases of petit mal, especially, we have observed that applications of the galvanic current to the cervical ganglia of the sympathetic had precisely the same effect in interrupting temporarily the frequency of the paroxysms as the bromide of potassium.

The method of electric treatment that promises most in this disease is central galvanization. Another method is to place one of the poles over the point whence the aura proceeds, and the other over the nerve-centers.

CHAPTER XXXIII.

DISEASES OF THE SKIN.

There are several theoretical considerations that would lead us to suppose that electricity might be of service in the treatment of diseases of the skin:

1. Pain and itching, oftentimes of a very distressing character, accompany many of the diseases of the skin, and of all the known methods of relieving and curing pain, electricity is one of the most satisfactory. If the application of the galvanic or faradic current may bring relief in headache, in spinal irritation, in the various forms of neuralgia, in rheumatism and in sprains, why should it not afford similar relief in the tormenting agonies of psoriasis, eczema, and prurigo?

2. Ulcers, sinuses, and bed-sores have long been treated by the galvanic and faradic currents with gratifying success; and it would be natural to suppose that the ulcerous conditions of some of the diseases of the skin might similarly be benefited.

3. Tumors and morbid growths of various kinds are discussed by the electric currents, and especially by the galvanic current, and it would be reasonable to infer that cutaneous indurations and hypertrophies might be discussed or diminished in a similar manner.

4. Those who hold the theory that some of the diseases of the skin are of a nervous origin, or are in some way intimately dependent on the brain, spinal cord, or sympathetic, would find still another theoretical argument in favor of introducing electricity into dermatology, since nervous diseases have long been regarded as *par excellence* the diseases most amenable to electric treatment.

The electro-therapeutics of diseases of the skin belong both to medical and surgical electricity. The tendency in recent times has been to transfer dermatology from surgery to medicine, and at present many of our most eminent dermatologists are physicians more than surgeons. This tendency is further strengthened by the modern views of the pathology of cutaneous disorders, particularly in regard to their relation to the nervous system. The purely local treatment of diseases of the skin by electricity might be regarded as belonging to electro-surgery, while their general and central treatment certainly belongs to electro-medicine.

Current Employed.—While both currents—the faradic and galvanic and even static electricity have proved useful in the treatment of diseases of the skin the galvanic appears to act more efficiently and to fulfil a larger variety of indications than the others. The reason of this will be sufficiently clear to those who understand the general differential indications for the use of the different forms of electricity. The peculiar electrolytic action of the galvanic current, which the faradic current possesses to but a feeble degree, is indicated in diseases of the skin for the same reason that it is indicated in the discussion of tumors. For the relief of the symptoms of itching and pain, the faradic current is frequently sufficient, especially in prurigo; its effects are also curative, but to a less degree than the galvanic current. The galvanic current also acts more powerfully on the central nervous system.

Methods of Application.—Diseases of the skin may be treated electrically in two ways—by applications to the diseased surface, and by central galvanization. In the first method the disease is affected directly; in the second method it is affected indirectly through the nervous system.

Application to the Diseased Surface.—Our usual method of galvanizing the affected part is to place an adjustable electrode of from two to four inches in diameter over the point where the principal nerve that supplies the part is most superficial—as the popliteal space, the anterior crural region, the border of the flexors of the arm, etc., while the negative is applied to the diseased surface by any convenient electrode with a broad surface. This is the method that we usually adopt in the treatment of ulcers. We are not able to say how much advantage there may be in applying one of the electrodes over the nerve. We suspect that it may be of service in improving the nutrition of the part that it supplies; it certainly cannot do harm in that position unless the *séance* is very much protracted. One electrode may be placed on some indifferent point, as the feet, or the hands, or on the thigh, where currents are borne well and can do no harm, however long they may be kept there. The electrode is sometimes kept firmly planted on the skin (stable), and sometimes is slowly glided from one part to another (labile). When the part is much abraded only mild currents will be borne, while in the immediate neighborhood a very strong current may not be felt at all. It therefore becomes necessary to modify the current continually according to the sensations of the patient, so that the treatment may never be excessively painful. There is yet no evidence that very severe applications have any advantage over mild applications. The pain of the galvanic current increases with the length of time that the electrode is kept in a fixed position without breaking the current; for this reason it is necessary, when strong currents are used, to shift the position of the electrode every minute or so, or as often as the patient complains of severe pain. We are not able to say whether the best results are obtained by stable or by labile applications. The electrolytic action of the galvanic current is most decided when there is little or no interruption to the current. When the faradic current is used we generally make labile applications.

Both electrodes may be applied on the diseased surface. The advantage of this method is that it economizes time and labor where there are numerous and large patches that need to be treated. Although the electrolytic action of the negative pole is greater than that of the positive, yet both act electrolytically, as all physicians know, and both act curatively as experience shows.

The amount of pain caused by a given current strength depends very much upon the individual idiosyncrasy, and upon the size and character of the electrodes. It is safe to say that a current strong enough to be distinctly but not painfully felt is generally indicated, and this strength is usually within the range of from five to twenty-five milliamperes.

Local Faradization Generalized. — We have applied this term to a method of using electricity which combines the advantages of localized and general faradization. Although we first used it in diseases of the skin, it may be employed to meet the same indications as general faradization; but since it requires absolute or approximative stripping on the part of the patient, it would be called for only in a limited class of affections.

In this method the operator takes hold of both the electrodes by their insulated handles, and passes them, within a few inches of each other, over all the diseased surface of the body. The electrodes may be kept stationary over spots where the disease is especially prominent. The method may be modified in various ways. One electrode may be kept fixed on some particularly bad spot, while the other is glided up and down the surface adjacent, or both electrodes may be kept fixed a part of the time. An advantage of this method, which may be employed with either current, is that it economizes time and labor, a very important consideration in cases where a large portion of the surface of the body is diseased.

This method is especially indicated in cases where nearly the entire surface of the body is affected by disease, as in general prurigo and psoriasis. Either current may be used in this way.

General Faradization.—This method of using electricity is usually not indicated in diseases of the skin, and for the reasons already given. For those cases that are associated with general debility as a result or cause of the disease of the skin, it may be employed with advantage; one pole may be applied at the coccyx by an adjustable electrode, or at the feet by a copper or tin plate, while the other is passed over the surface of the body.

Electric Brush.—When the skin is not itching or anæsthetic the electric brush is very painful, and is therefore to be recommended chiefly for cases where there is very great irritation, or itching and anæsthesia. We have frequently found it more efficacious than the ordinary sponge electrode. In some conditions of eczema an application which in health would be unendurable is positively agreeable. The distinctively surgical methods of treating certain diseases of the skin by electrolysis and galvano-cautery will be described in Electro-Surgery.

Central Galvanization.—This important method of using electricity we have proved to be of great service in the treatment of certain diseases of the skin, especially of chronic eczema and prurigo. Under this method of treatment alone, without making any application whatever to the diseased surface, the itching and burning of these diseases are relieved sometimes immediately, and under a protracted treatment permanent cures are obtained. The results obtained by this method are of the highest possible interest in a pathologic point of view, as showing a kind of dependence of chronic eczema on the nervous system that had not before been suspected.

Diseases of the Skin for which Electric Treatment is Indicated.—Under this head we sum up the results of electric experience up to the date of publication.

Eczema.—This disease we place at the head of the list, for the reason that we have found more rapid, brilliant, and uniform results from electric treatment in this than in any other disease of the skin. We have treated the chronic forms in different parts of the body, and in nearly all cases thus far with immediate relief of the distressing pain, and ultimate cure after a course of treatment. We have used for this affection, almost exclusively, the galvanic current, either locally or centrally. Patients have come to us declaring that the distress is so great that they would be glad to have the suffering part amputated, and after an application of from five to fifteen minutes have gone out entirely relieved. This relief lasts for several hours, sometimes for days, and the pain grows less and less until the cure is accomplished.

It is in this disease especially that "central galvanization" alone, without making any application whatever to the diseased part, has accomplished such striking results.

Prurigo.—If electricity could do nothing more than relieve the itching of prurigo, it would be entitled to an honorable place in the armamentarian of the dermatologist. Dry faradization alone may bring relief in a very few minutes, and, when perseveringly used, may cure. We have seen immediate relief follow general faradization used in the ordinary method with wet sponges. In this disease also central galvanization alone has in our hands been very effective.

Lichen.—We have had no opportunity to treat a marked case of lichen; but there is every probability that electricity would accomplish as much in this affection as in the other symptoms of the so-called dartrous diathesis.

Anæsthesia.—For the curable cases of cutaneous anæsthesia, faradization is a specific, if any remedy can be said to be a specific for anything. Even cases that depend on incurable central lesion may improve very decidedly under treatment. In cases of paralysis of motion and sensation, the sensation may be partially or completely restored under electrical treatment, even when the loss of motion remains unchanged.

Anæsthesia is a condition for which the electric brush is particularly indicated.

Acne.—If we were to judge from our own limited experience in the treatment of acne, we could not speak very encouragingly.

Liebig and Rohe speak favorably of the effects of the dry faradic brush in those cases where there are many comedones and few pustules, and Hayes has seen good results follow electrolysis.

Acne Rosacea.—Whether acne rosacea is different, pathologically, from ordinary acne or not, it certainly yields better to electric treatment. On the theory that the disease may depend in some way on the digestive organs, central galvanization may be tried in connection with local treatment.

External treatment demands a current of from 5 to 10 milliamperes, but in the use of the needles from 1 to 3 milliamperes are sufficient.

Psoriasis, and *Pityriasis*, in their relation to electro-therapeutics, may be divided into two classes: (1) Those cases that are benefited up to a certain point. (2) Those cases that receive but little, if any, benefit. Judging from our own observations, we should say that the latter class (those who do not yield at all) are in the minority. Some cases progress very slowly, and need months of treatment. The negative pole of the galvanic current seems to be more efficacious in this disease than any other method. For the sake of economizing time, however, we frequently use both poles, with broad electrodes.

The results have not been very satisfactory. Even when decided improvement takes place under long treatment relapses may occur, and the cure has never in our hands been complete.

Ringworm.—Common ringworm is as a rule much benefited by the galvanic current.

Scleroderma.—This disease of the skin, usually so obstinate to recognized methods of treatment, may be treated by strong localized galvanization with considerable benefit. Fieber, of Vienna, records a case where peripheral galvanization combined with galvanization of the sympathetic were very effective. In a case that we saw with Dr. Piffard and for a time treated with him, a very persevering use of the galvanic current had a decidedly beneficial effect.

Chromatogenous Diseases—Leucoderma, Melanoderma.—The chemic or catalytic action of the galvanic current is theoretically indicated in chromatogenous or pigmentary diseases. With leucoderma or whiteness of the skin, and ephelis or sunburn, and in lentigo or freckles, no experiments, so far as we know, have yet been made. Dr. Wm. R. Fisher, of Hoboken, has treated a case of melanoderma of the face by the galvanic current, and gained a complete cure. The spot, which was about half an inch in breadth and three-quarters of an inch long, looked like a spot of mud on the cheek. Through the courtesy of Dr. Fisher we had opportunity to see this case both during the process of the treatment and after recovery.

Elephantiasis.—In the earlier issues of this work we reported a case of elephantiasis where much temporary relief followed electric treatment. No other case has fallen under our observation, and it is not probable that electricity has much power over the disease. Reference should, however, be made to the experience of Dr. Aranjo, a South American practitioner, who treated many cases, mostly by electrolysis, and claimed to have cured one case after five years of effort.

Alopecia.—In this condition, local galvanization has been used with some benefit. Our own observations in this particular affection have not been very extensive.

The question that has been often asked us, whether parasites on the skin can be killed by a current that the patient can easily bear, we are unable to answer, but that they can sometimes be destroyed by cataphoric action is probable.

Tinea.—In this parasitic disease of the skin the cataphoric action of the galvanic current has been successfully used by Charon and Gevaert, of Brussels. Reynolds * also reports favorable results by this method. The best solution for the cataphoric electrode would appear to be the bichloride of mercury.

Hyperidrosis.—Hyperidrosis is said to be a functional disorder of the sweat glands, but in its unilateral form at least it would seem rather to be dependent on some disturbance of the sympathetic. Cases reported by Seguin † and by Ebstein ‡ and ourselves § point to this.

Permanence of the Results.—The very natural question, whether the results obtained by electricity in diseases of the skin are more permanent than those obtained by ordinary methods, the future must answer. That relapses may occur after a cutaneous disease has even yielded to electric treatment, already has been demonstrated. To what extent central galvanization and genereal faradization combined with local treatment can control the diathesis must be ascertained by patient and persistent experiment.

That the results of electric treatment are, to say the least, as permanent as those derived from the accepted methods, and that after the accepted methods have partially or entirely failed, electricity, either alone or in conjunction with the accepted methods, may succeed, we have satisfactorily established.

* "A New Method on the Treatment of the Vegetable Parasitic Diseases of the Skin."

† American Journal of Medical Sciences, October, 1872.

‡ Virchow's Archiv, 1875, Bd. lxii.—quoted by Eulenburg and Guttman.

§ New York Medical Record, August, 1895.

Superfluous Hairs.—That hairs can be successfully and permanently removed by electrolysis is now an established fact. The appliances necessary are a pair of tweezers to seize the hair, an exceedingly fine irido-platinum needle, and a needle-holder (Fig. 134) which is to be connected with the negative pole of the battery. The patient being seated in a high reclining chair and exposed to a good light, the operator seizes the hair with the tweezers held in one hand, while with the other the needle is introduced by the side of the hair into the follicle. The patient then applies the positive pole to the palm of her hand. In a few seconds some hyperæmia, followed by a slight blanching and a little froth, will appear around the needle, and in from twenty to forty seconds the hair become loose in the follicle and is readily withdrawn. The current-strength should be just sufficient to do the work. Approximately, from one-half to two milliamperes will answer the purpose.

The pain is but slight, and if the work is skilfully done but little, if any, scarring will follow.

In a case referred to us by Dr. Coutant, of Tarrytown, N. Y., we removed in the course of a year several thousand hairs, with the result of rendering presentable a face that would otherwise have been almost entirely covered with hair.

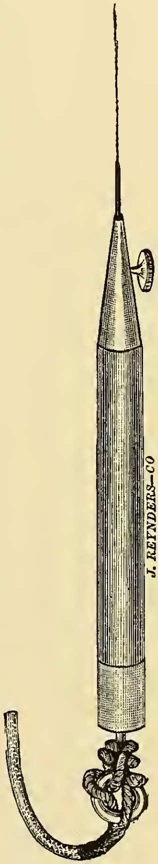

FIG. 134.—Epilation Holder with Needle.

"A difference of opinion exists as to the effects of the electrolysis upon the finer hairs which are not removed. It is a matter of importance to know whether the removal of the coarser hairs upon a woman's lip or chin does or does not stimulate the growth of the finer ones, and yet it is a question not easily determined. In some cases the unknown cause of the growth is still active and there is a marked tendency of the finer hairs to become longer and coarser. In such cases the patient usually believes that pulling out or cutting off the hairs increase the growth. I am skeptical on this point, as I have seen so many cases where the growth has steadily increased although the patient has never cut or pulled a single hair. In a large proportion of cases, on the other hand, the unknown cause of the growth has ceased to act, and the removal of the abnormally developed hairs leaves the face permanently free. As the growth of hair is undoubtedly the result of a perverted action of the nerves which should control the nutrition of the hair bulbs, it would seem plausible that an electric current would prove a healthy stimulus to the part, and restore the normal function of these nerves. But this is mere theory. As a matter of fact, I have observed in several cases where the tendency to an increased growth of the downy hairs has been marked, that the removal of the coarser hairs has been followed by a cessation of this morbid tendency. I believe, therefore, that if the use of electrolysis in the removal of coarse hairs has any effect whatever upon the development of the finer ones, that this effect is beneficial." *

* "The Use of Electricity in the Removal of Superfluous Hairs," etc., by Geo. Henry Fox, M.D.

CHAPTER XXIV.

DISEASES OF THE ORGANS OF DIGESTION.

Among the diseases or symptoms of disease of the organs of digestion for which electricity has been employed with more or less success, are dyspepsia, jaundice, constipation, chronic diarrhœa, gastralgia, abdominal neuralgia, vomiting or regurgitation, and flatulence.

Electro-Diagnosis.—Irritable conditions of the stomach, liver, and intestines are sometimes revealed by their sensitiveness to the electric current. Pains must be taken to distinguish the sensitiveness of the skin from that of the internal organs.

Irritability or ulceration of the large intestines is sometimes indicated in a very marked manner. For the diagnosis of the diseases of these organs, the faradic current, on account of its superior mechanic effects, is preferable to the galvanic.

In nervous dyspepsia there is frequently a peculiar and very unpleasant tenderness in the epigastric region, so that only a very mild current can be borne. In some cases a thrill, with a sinking sensation, is felt when the electrode with a strong current is passed down the spine; in other cases the application of a strong current at the cilio-spinal centre, or on the crown of the head, causes a feeling of nausea. The spinal irritation, on which nervous dyspepsia so frequently depends, is indicated by tenderness of the dorsal vertebræ, as revealed by pressure or application of the current.

General Principles of Electric Treatment.—Electric treatment is serviceable in the diseases of the organs of digestion in two ways: First, by improving the nutrition of the tissues of the organs; secondly, by improving the nutrition of the brain, spinal cord, sympathetic, and entire nervous system. The tonic influence on the nervous system may be obtained by central galvanization, and by general faradization.

The mechanic influence on the tissues of the viscera may be obtained by general or localized faradization. A fundamental fact of great importance in the treatment of disorders of the digestive tract is this, that for applications to the abdominal viscera, stomach, spleen, liver, intestines, and uterus, the faradic current is usually preferable to the galvanic. The reason for this is that the faradic current acts more vigorously on the muscles than the galvanic, and therefore produces more powerful mechanic effects, with passive exercise of all the deep tissues. It may be safely said, then, that we know of no treatment more sure to relieve the leading and concomitant phenomena of nervous dyspepsia than general faradization and central galvanization. In connection with this we sometimes use galvanization of the sympathetic, the pneumogastric, and spine. General faradization relieves nervous dyspepsia, not so much by the virtue of its influence on the stomach—although it directly affects the stomach—as by its influence on the nervous condition of which the dyspepsia is a symptom.

The number of our cases in which dyspepsia was the only symptom is comparatively small; the number in which it was a prominent accompanying symptom is quite large. Most of the cases of hysteria, nervous exhaustion, and hypochondriasis, and very many of the cases of neuralgia and paralysis, were more or less complicated with dyspeptic symptoms. Relief of dyspepsia is one of the earlier signs of improvement under electrization, even when treating cases in which it is merely an incidental condition.

The stomach and liver may be indirectly galvanized through the pneumogastric in the neck; the stomach, liver, spleen, kidneys, and intestines may be directly faradized by applying large electrodes with very fine pressure over the back and abdomen, so as to pass the current directly through the organ that we wish to affect. Except in cases of disease, these organs will bear strong currents without severe discomfort. Either stable or labile applications may be used, without regard to the direction of the current, from three to ten minutes, or even longer.

In connection with nervous dyspepsia, we find associated atony of the stomach. Atony of the stomach cannot exist for a long time without developing into dilatation. For the purpose of stimulating to contraction the muscular coats of the stomach, electricity is manifestly the very best agent at our command. By stimulating contraction and relieving the dilatation, we directly aid in overcoming the atony, the primary cause of all the subsequent difficulty. Although the galvanic current is recommended by some, who give very definite instructions as to the method to be employed, the faradic current is to be preferred. External applications, although sometimes of service, are too frequently inefficient, and more active and direct treatment should be resorted to. Applications should be made directly to the interior of the stomach by means of olive-shaped electrodes, fashioned in the bipolar form.

The induced currents of quantity are far more effective in these internal applications than those of tension.

Prognosis.—For the temporary or permanent relief of nervous dyspepsia, the prognosis under the treatment above indicated is exceedingly favorable, and the results obtained by general faradization and central galvanization alone are some of the most remarkable in therapeutics. Cases of nervous dyspepsia, with their manifold complications, are on the whole the best tests that can be offered for this method of treatment. Not only are the purely dyspeptic symptoms relieved, but there is great improvement in sleep, and in strength of muscle and brain, and in some cases very marked increase in weight. Relapses are not unfrequent in this disease, especially under bad hygiene; for with many the tendency to nervous dyspepsia is hereditary, and is continually liable to manifest itself.

Constipation, Chronic Diarrhœa, and Jaundice.—Constipation, associated with and constituting a part of nervous dyspepsia, is, like dyspepsia, disposed to yield rapidly, and often permanently, to electrization. Next to insomnia, it is the symptom first to yield, after general faradization is used, even though there may be subsequent relapse. Very many of the cases related under dyspepsia, hypochondriasis, hysteria, and nervous exhaustion, were to a greater or less extent troubled with constipation, even when this symptom was not specified; and in the majority of cases there was important relief.

The relief is sometimes merely temporary; relapses are most likely to occur in those cases that are of a hereditary, or at least life-long character.

It not unfrequently happens that a strong application is followed the next or even the same day by a freer alvine discharge than usual. Constipation, much more frequently than is supposed, depends on an irritable, exhausted, or congested condition of the spinal cord. That myelitis and the more serious lesions of the spinal cord are accompanied by a deranged condition of the bowels, either constipation or diarrhœa, is fully recognized; it is not, however, so well understood that spinal irritation, even in its milder degrees, may have constipation for one of its symptoms, and that this symptom will disappear with the removal of the cause, by treatment directed to the spine. For those cases that result from incurable disease of the brain or spinal cord only temporary relief can be obtained. In such cases relapse usually occurs as soon as the treatment is discontinued. Very obstinate and life-long cases of constipation sometimes are not benefited by any form of electric treatment.

Electrization may be said to relieve constipation in several different ways:

1. By its general tonic effects on the system at large, on the same principle that it relieves nervous dyspepsia.

2. By its tonic effects on the central nervous system, and especially on the spinal cord. On account of the fact that very many cases of constipation depend on a morbid condition of the cord, special attention should be given to the spine, whatever may be the method of electrization employed.

3. By its direct effects on the organs of digestion. The mechanic action of the faradic current especially gives tone to the stomach, liver, and intestines, markedly increases the hepatic and intestinal secretions, and aids the peristaltic action of the intestines. The galvanic current is also

frequently efficient. By introducing the negative electrode and using from one to two milliamperes without current interruption for two or three minutes, some cases will respond immediately.

In jaundice the results of our experience have been more favorable than the reverse. In chronic diarrhœa we have succeeded in a number of striking instances.

The treatment of all these conditions is worthy of far more attention than it has thus far received from electro-therapeutists.

In some cases of very obstinate constipation it is of advantage to localize the current by internal applications. This may be accomplished by means of a rectal electrode (Figs. 135, 136). This may either be non-

FIG. 135.—Unipolar Rectal Electrode (Kidder).

FIG. 136.—Bipolar Rectal Electrode (Kidder).

insulated, or insulated up to a point near the tip, and may be double or single. A very powerful current may be borne in the rectum without discomfort. The other pole may be applied at different points over the abdomen.

Ileus (*Invagination*).—We recently treated a case where powerful faradization availed to cure constipation when the ordinary remedies had been tried in vain. The negative pole was applied to the spine, and the positive passed over the abdomen in the region of the large intestine. In a few moments very abundant evacuation appeared.

Dr. Clemens, of Frankfort, states that he has successfully treated invagination by first administering one or two tablespoonfuls of metallic mercury, which settled down to the seat of the invagination. The negative electrode was applied over the supposed seat of the disease, and the positive in the rectum. Voltaic alternatives were used.*

That the opposite symptoms—diarrhœa and constipation—are treated successfully by electricity need surprise no one who thoroughly comprehends the fact that electric treatment improves nutrition and so may be used to combat any diseases that depend on depraved nutrition, whatever the symptoms by which the depraved nutrition manifests itself.

* Althaus, op. cit., p. 603.

Regurgitation and Vomiting.—For those cases of vomiting that are of an obviously nervous character, galvanization of the sympathetic and pneumogastric, or strong faradization through the stomach, is sometimes of important service. Successful results have been obtained by Pepper and Bricheteau. The latter treated with success several cases of vomiting of pregnancy. His method of application was to place the electrodes on the epigastrium at the commencement, middle, and close of the meal.

It is well in such cases, especially if they are obstinate, to try a variety of methods: galvanization of the sympathetic and vagus, and of the spine, faradization through the stomach with a strong stable current, and general faradization.

Flatulence.—Flatulence is a symptom of disorder of the digestive organs that very readily yields to electric treatment. It demands the same treatment as dyspepsia and constipation. Those very frequent cases that depend on spinal irritation and congestion, and on hysteria, need central galvanization or general faradization; cases that depend on an attack of acute indigestion may be advantageously treated by internal applications, one pole being applied to the rectum by the rectal electrode, and the other to the spine or abdomen.

Flatulence was a symptom in very many of our cases of dyspepsia, hysteria, and spinal irritation, and almost uniformly it temporarily or permanently yielded.

Intragastric Electrization.—Of late intragastric electrization has been warmly recommended by Dr. Max Einhorn, of New York. According to this writer, the method of procedure is as follows: * When fasting or about an hour after a light breakfast, the patient drinks a glass of water and then swallows the electrode, which is so constructed that no metal touches the tissues, the current being transmitted through the holes in the hard-rubber covering and through the water to the stomach. The other electrode is applied externally.

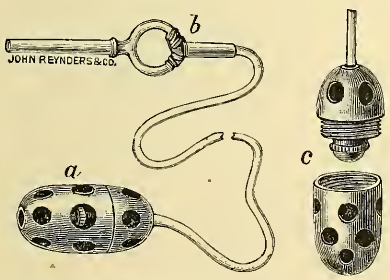

FIG. 137.—Einhorn's Stomach Electrode.

In withdrawing the deglutable electrode a resistance is felt at the introitus œsophagi; it is not advisable to pull the electrode with force. One has only to make the patient swallow once or twice, and to make use of the moment when the larynx, by this act, ascends and the passage becomes free, to withdraw the electrode, which is done with perfect ease. In this method of treatment both faradic and galvanic currents are utilized.

* New York Medical Journal, July 8th, 1893.

With regard to the value of intragastric electrization, Einhorn concludes as follows:

1. Direct gastro-electrization is a potent agent in the field of chronic (non-malignant) diseases of the stomach.

2. Gastro-faradization appears especially useful in most cases of dilatation of the stomach and enteroptosis; further, in atonic conditions of

FIG. 138.—The Ball Apparatus of the Gastrograph. (Natural size.)

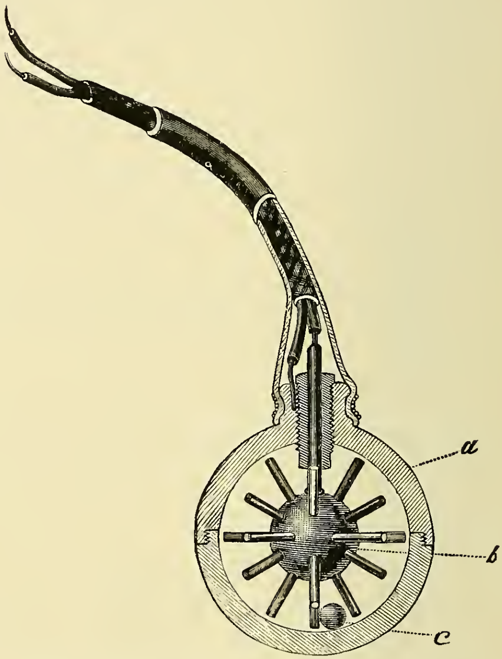

FIG. 139.—Cross-Section of the Ball, showing interior construction. (Enlarged three and a half times.) *a*, The two hemispheres; *b*, the spiked ball; *c*, the platinum ball.

the cardia (ructus) and pylorus (presence of larger amounts of bile in the stomach), and in chronic gastric catarrh (gastritis chronica glandularis).

3. Gastro-galvanization is almost a sovereign means for combating severe and most obstinate gastralgia, no matter whether their origin is of a nervous nature or caused by a cicatrized ulcer of the stomach.

4. Gastro-galvanization exerts also a favorable influence on several affections of the heart complicated with gastralgia.

With a view of determining the mechanical action of the stomach Einhorn has devised the "Gastrograph." The whole apparatus comprises: 1. The ball (being the principal part). 2. A few electric cells. 3. The ticker.

The ball (Fig. 139) consists of two hollow metallic hemispheres (*a*), which are screwed together; within it is lodged and attached to the upper hemisphere, but perfectly insulated from the same at the attachment, another ball provided with spikes (*b*) radiating in all directions, but not touching the inside walls of the hemispheres; another very small platinum ball (*c*) lies within the large ball and can freely move in all directions, knocking at the spikes (see Fig. 139). Two insulated wires—one connected with the hollow ball, the other with the spiked ball—are encased in a very fine, thin rubber tube, forming the cable, and separate at the end into two branches, which must be attached to an electric battery. As soon as the platinum ball touches one of the spikes an electric circuit is made; as soon, however, as the platinum ball moves a little aside and does not touch the spike any more, the current is broken. At each motion of the ball apparatus a rolling of the little platinum ball takes place and the electric current is either closed or broken. When the apparatus is a

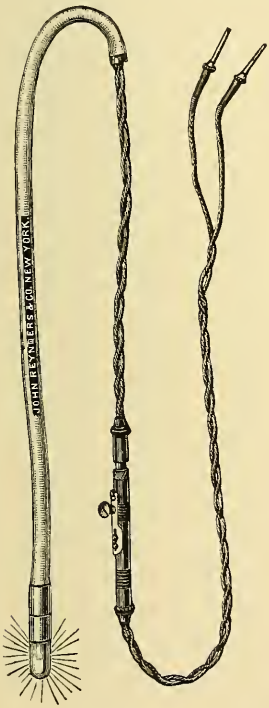

FIG. 140.

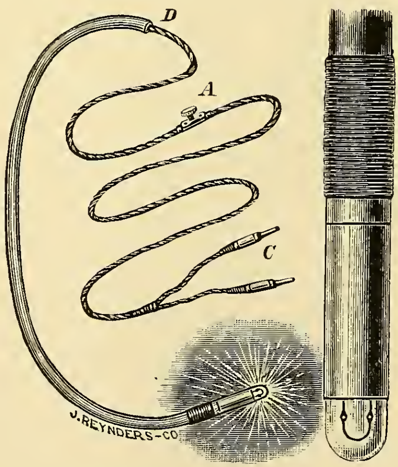

FIG. 141.

Einhorn's Gastrodiaphane for Transillumination of the Stomach.

rest there is no change in the current. In connecting the "ticker" with the battery and the ball, each motion of the latter will be recorded on the paper in showing the "breaks" and "makes" of the current.

If the ball is swallowed and brought into the stomach, the motions of it—which are caused by the active and passive motions of the stomach—can be recorded in the same way as described.

The gastrodiaphane (Figs. 140, 141) consists of a soft-rubber tube, at the end of which is fastened an Edison lamp of hard glass by means of a small metal mounting; conducting wires run to the battery; at some distance from the rubber tube there is a current-interrupter. The insertion of this apparatus into the stomach is no more difficult than that of the ordinary tube alone. The patient, in a fasting condition, drinks one to two glasses of water, and thereupon the apparatus, lubricated with glycerin, is inserted. The examination must take place in a dark room. The outlines of the stomach are visible as a reddish zone on the abdomen.

1. It enables the operator to recognize quickly a dilatation of the stomach.

2. The condition called gastroptosis can with certainty be pointed out.

3. One is enabled to perceive tumors or thickenings of the front wall of the stomach by their lack of translucency.*

* New York Medical Journal, December 3d, 1892.

CHAPTER XXV.

DISEASES OF WOMEN.

In a work such as this—devoted generally to the subject of electricity in medicine—it is manifestly impossible to go into a minute detailed description of the principles and methods that govern the use of this agent in gynecology. The literature pertaining to the subject has accumulated beyond measure. Much if not most of it is simply a restatement of the first original, really valuable contributions to the subject, and not a little of it is valueless from the standpoint of correct clinical observation. Three things have combined in placing upon a better foundation the electro-therapeutics of the diseases of women.

1st. The milliameter. 2d. A more correct knowledge of the physical, physiologic, and chemic action of the different forms of electricity, and a better appreciation of the differential indications for their use. 3d. A knowledge of better methods of overcoming the external resistance of the body, thus enabling us to localize internally currents of far greater strength than was before possible. In applying the galvanic current internally, the milliameter is not only necessary but is absolutely indispensable. In external applications, when the dosage generally given is much smaller, the sensation of the patient is something of a guide, and one may often venture and do safe work without this indicator of current strength. In applications, however, by electro-puncture, by metal electrodes to the uterine cavity, or by the method of interstitial electrolysis the case is widely different. The sensation of the patient affords but a poor guidance, and without his milliameter the physician subjects himself to the "caprice of hazard." The current is likely to be either too strong, or so weak as to be useless. The milliameter, therefore, has aided much in revolutionizing the galvanic treatment of women by substituting mathematical accuracy for the vagueness of empiricism.

We have again learned to appreciate better the differential action of the two poles—the positive and negative—through which we get in the galvanic current especially a double-edged weapon. At the positive pole the acids accumulate and oxygen is liberated. It is therefore hæmostatic, and possesses certain clearly defined indications. In ulcerations, hemorrhages, and leucorrhœal discharges the positive pole is mainly indicated and produces results both immediate and remote.

It immediately suppresses hemorrhage through its coagulating properties, and secondarily, its tendency is to prevent further hemorrhage on account of the retractibility of the cicatrices left by the action of the pole. The negative pole, on the contrary, at which point the alkalies accumulate and the hydrogen is liberated, is indicated in the non-hemorrhagic forms of uterine disease. Its action is stimulating and derivative. It has special power in exciting the process of absorption—a process which often continues long after the current ceases to flow.

The third impulse given to the development of the modern treatment of the diseases of women by electricity has been an appreciation of the necessity of larger doses in local treatment and a practical knowledge of how best to obtain these large doses with the limited voltage that the

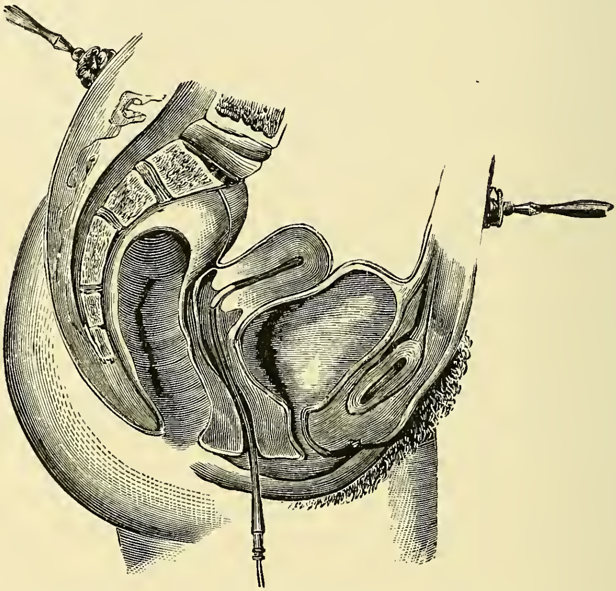

FIG. 142.—Faradization of the Uterus. One of the poles is connected with a bifurcated electrode, one branch of which is placed on the lumbar, and the other on the hypogastric region. The other pole is applied in the cervix (or at the os) by an insulated uterine electrode. (The normal position of the uterus is after Wieland and Dubrisay.

majority of physicians have at command. It is all a question of resistance, and Ohm's law explains it; but nevertheless it was due to Apostoli that difficulties in this direction have been overcome, and the therapeutic possibilities of electricity in gynecology immensely enlarged. In this country certainly, Engelmann deserves especial credit in making clear Apostoli's ideas in the rational use of electricity in the treatment of uterine disease.

Nearly all the diseases of the female sexual organs have been treated with a greater or less degree of success by electricity. They include the disorders of menstruation, considered merely as symptoms of constitutional disturbance as well as dependent upon local disease, leucorrhœa, chronic pelvic cellulitis, uterine hyperplasia, sub- and super-involution, atrophy of the uterus, displacements and prolapses, ovarian neuralgia and ovaritis, peri-uterine hæmatocele, stenosis of the uterine canal, cystic growths, fibroid and ovarian tumors, and chronic metritis and salpingitis.

Treatment of Diseases of the Uterus.—Local, central, and general treatment may be employed. The local treatment may be either external or internal.

External Method.—Externally, the uterus and its appendages may be electrized by placing one pole with firm pressure over the hypogastric region, and the other over the lumbar region of the spine.

FIG. 143.—Rockwell's Uterine Electrode (Kidder).

FIG. 144.—Gunning's Flexible Uterine Electrode (Kidder).

FIG. 145.—Bipolar Intra-Uterine Os Uteri Electrode (Galvano-Faradic Mfg. Co.).

This method is sometimes as effective as internal applications in certain cases of amenorrhœa and dysmenorrhœa especially and, in virgins at least, should always be tried at first. In this method benefit is derived partly from the effect of the current on the lower part of the spinal cord and the abdominal ganglia of the sympathetic.

Internal Method.—Electric currents may be localized in the female organs of generation in a variety of ways. One pole may be applied to the os by means of an insulated electrode with a metallic bulb (Fig. 143), while the other, with a broad electrode, is applied to the back, or on the hypogastric region, or over one of the ovaries. Instead of a metallic bulb the uterine electrode may be composed of branches to clasp the cervix. A much stronger current can be borne at the cervix than would be supposed.

Treatment of the Uterus by the Faradic Current.—Methods of faradizing the uterus are represented in the accompanying cuts (Figs. 148, 165).

The basis of the instruments represented in the cuts for ordinary intra-uterine applications is similar to Sims' sound. One of these (Fig. 145) is insulated up to within one-half inch of the extremity.

It represents a double intra-uterine electrode which allows one pole to act on the uterine canal and the other on the os externum.

Figs. 146 and 147 represent the two forms of the bipolar electrodes for intra-uterine and vaginal applications of the faradic current. For information concerning the use of these electrodes and the remarkable difference in the physiologic and therapeutic effect of the induced currents of quantity and tension when applied to the vagina and uterus by the method of bipolar faradization, the reader is referred to the section devoted to this subject.

FIG. 146.—Apostoli's Bipolar Intra-Uterine Electrode for Faradic Current.

It is simply necessary to say here in regard to the method that both poles are localized internally, through the two metal surfaces at the end of each electrode. In Fig. 148 the bipolar intra-uterine electrode is seen in position with the positive and negative attachments at its lower extremity.

The Sinusoidal Current.—The alternating sinusoidal current applied in the uterine cavity is thought by many to be equal if not superior to the ordinary faradic current. As compared, however, with the new form of high-tension coil it does not seem to us to possess advantages.

FIG. 147.—Apostoli's Bipolar Vaginal Electrode for Faradic Current.

Like the current of the high-tension coil it possesses decided value in the alleviation of uterine pain, but it frequently fails to accomplish in this direction the good that comes from the use of the other.

Concerning these internal applications of the different currents of electricity to the uterus, it may be remarked:

First.—That in those cases where local treatment is indicated, applications to the cervix or in the uterus are frequently much more efficacious than external applications even with the strongest currents. For this reason it is necessary, even with virgins, to insist on internal treatment, especially after external treatment has failed. The uterine electrode (Fig. 143) can usually be introduced into the vagina as readily as the finger. The intra-uterine electrode can be introduced with or without the aid of a speculum.

The dispersing electrode may be applied to the back or abdomen.

Secondly.—Internal electrization is not so painful as external. Powerful currents can be borne at the cervix and in the uterus for a long time

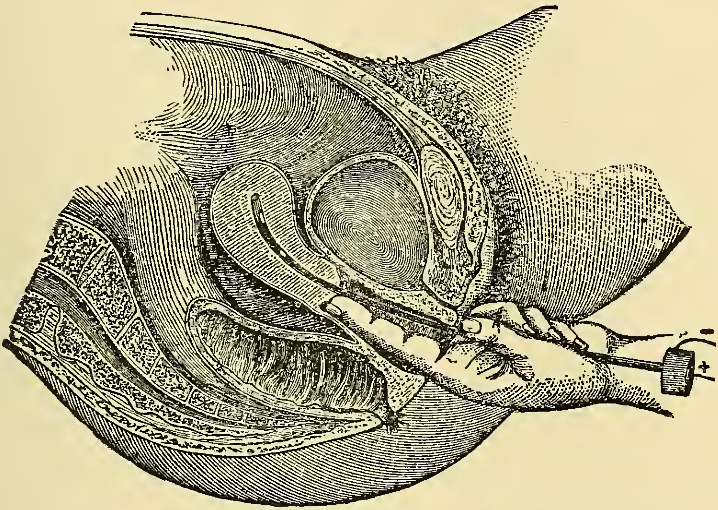

FIG. 148.—Bipolar Faradization of the Uterus.

without inconvenience. Patients usually complain more of the pain beneath the electrode which is applied on the back or abdomen, even when the negative, which is the stronger and more painful, is applied internally.

Thirdly.—Either current may be used. The galvanic as well as the faradic current may be localized in the uterus.

The vagina may be treated by a metallic vaginal electrode (Fig. 149) unipolar method, with which either the positive or negative pole may be

FIG. 149.—Unipolar Vaginal Electrode (Kidder).

connected, or by the electrode Fig. 147 (bipolar method). This is useful in vaginal leucorrhœa and prolapsus.

For these local applications either the galvanic or faradic currents may be used; the faradic is preferable in those cases where mechanical more than chemic effects are indicated. Especially is this the case in amenorrhœa. Furthermore, the currents may be stable or labile, uniform or increasing, according to the indications. Local applications to the uterus, whether unipolar or bipolar, external or internal, may be continued for from five to fifteen minutes. Several methods may be tried at each sitting.

Local treatment by the faradic current is essentially preventive in its action. It is now well understood that the great majority of uterine inflammations are due to circulatory troubles following confinements or abortions. There is an arrest of the retrograde metamorphosis, stasis of the circulation, and subinvolution. If now we can combat this slowness of the circulation much is done toward preventing subsequent inflammation, and in faradization we have a remedy which does this most effectually. It calls into contraction the smooth muscular fibres of the uterus, producing a sort of interstitial massage, hurries the circulation, accelerates the absorption of exudation, and so corrects a languid or perverted nutrition. The high-tension coil also, the effects of the current from which are fully discussed elsewhere, places in our hands a most efficient weapon in overcoming uterine and ovarian pains of a non-inflammatory character.

General and Central Treatment.—But very many, perhaps the majority of cases of functional disease of these organs require general, as well as localized electrization. There is no department in which so many mistakes have been made by too exclusively local treatment as in that of gynecology. No case of functional disturbance of the uterus should be abandoned by the electro-therapeutist until he has faithfully tried general as well as external and internal localized electrization. To treat symptoms of central or constitutional disturbance by merely local electrization is illogical in theory and unsatisfactory in practice. All the organs of generation in woman as well as in man can be affected by galvanization or even faradization either directly or reflexly along the spine. A strong evidence of the beneficial result of general faradization in these cases is the fact that patients undergoing treatment frequently remark that their menses are in some way affected. In some cases they are brought on before their time, in others much increased in quantity. So frequently does this happen that we prefer on the whole to suspend the treatment during the menstrual periods in those cases where no therapeutic effect is desired on the sexual organs.

The time of making the applications is not unimportant. It is an advantage, in amenorrhœa at least, to concentrate as many applications as possible during the few days that precede the appearance of the menses. And yet the advantage of this is hardly as great as has been supposed. The great thing in all but recent and temporary cases is to remove the anæmia or chlorosis, or nervous exhaustion with which the menstrual disorder is associated, and of which it is a prominent factor. Another suggestive consideration is that the menstrual flow may be brought on or increased through reflex action by localized electrization of other and distant portions of the body, as the hands, feet, chest, etc.

Treatment of the Uterus by the Galvanic Current.—As in the use of the faradic current the local treatment may be both external and internal, together with the central method (central galvanization), which is to the galvanic what the general method (general faradization) is to the faradic current.

To Apostoli, of Paris, belongs the credit of boldly overstepping the bounds thought to be safe in treating the uterus and its appendages by the galvanic current and using currents of great power. Hitherto, one important defect in the treatment of various uterine diseases, and especially morbid growths, has been the use of too weak currents. This has been due partially perhaps to a commendable caution in dealing with an agent so potent as electricity, but more to our lack of definite knowledge of the amount of current strength needed to accomplish certain ends, and our inability to readily command more than a certain limited working power from the apparatus in ordinary use. A third obstacle was the absence of any instrument by which the current could be accurately measured, and this, to the novice, was a defect practically insurmountable in his efforts for anything like uniform results.

The improved milliammeter (Fig. 68) has overcome this difficulty, and is indispensable in all electro-surgical operations, besides being a

FIG 150.—Apostoli's Platinum Electrode for Galvano-Puncture in the Treatment of Fibroid and Cystic Tumors.

vast aid in all electric applications. Instead of a strength of current equal to only 10 to 30 milliamperes, which was commonly used, and which indeed was all that could be obtained from the appliances in use, it is now no uncommon thing to use currents even of several hundred de-

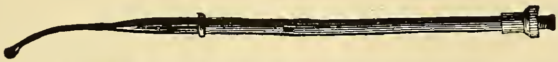

FIG. 151—Rockwell's Intra-Uterine Electrode for Galvanic Current.

grees of strength. For this purpose the external electrode must not only be material of the best conduction possible, but of suitable size and sufficiently flexible to be perfectly adjusted to every inequality of surface which it covers. The strength of current from a given number of cells is directly in proportion to the size of the electrodes. Thus, if from a series of cells, fifty in number, we obtain, when the current is passed through electrodes of a certain size, a strength of 50 milliamperes, electrodes of similar pattern, but double the size will yield a current strength of 100 milliamperes. As to the quality of the electrodes—sponges are too bulky and offer too great resistance when our object is strength of current.

As a substitute, Apostoli uses sculptor's clay held in place by gauze (Fig. 153). This material holds moisture fairly well, can be adapted closely to the skin, and is undoubtedly an admirable electrode. The objection to-day, however, is that it is dirty and difficult to handle without soiling the clothes and person of both the physician and patient. To overcome this difficulty and thus render available this most useful material, we have devised the electrodes illustrated in Figs. 158 and 159.

These electrodes are of non-conducting material (hard rubber) and are made of any size. The bottom of the disk is covered with block tin. This is an important feature, since with the strong currents used ordinary metallic conductors speedily become oxidized at the positive pole and their efficiency impaired. Block tin for all ordinary purposes is practically non-oxidizable. When wanted for use the electrode is simply completely filled with the moistened clay so that the edges of the disk are entirely covered. With an electrode of this kind two inches in diameter, one can readily bear 50 to 75 milliamperes, and in the well-known law that the greater the area the less the resistance, we have only to enlarge our electrode to obtain with the same electro-motive force an increased current strength that is just as easily borne, since it is distributed over a larger area. An electrode that answers well, however, for the ordinary purposes of local application consists of layers of absorbent cotton spread smoothly over flexible metal backs of varying size (Fig. 154).

The material is easily obtained, and so inexpensive as to warrant a fresh supply for every patient. In all this, reference is, of course, made to the external electrode, which in the treatment of the uterus and its appendages is usually placed upon the abdomen.

The internal electrodes consist mainly of a small metal or carbon bulb or cup attached to a long insulated stem (as in Figs. 143 and 144), for applications to such portions of the uterus as can be reached per vaginam, metal probe-electrodes for intra-uterine applications as in Figs. 151 to 157, and needles of varying sizes for electro-puncture (Fig. 150). It should ever be borne in mind that when the positive pole is applied to the interior of the uterus the metal used should be of some non-oxidizable metal, such as platinum or gold, although smooth carbon stems are also used.

Figs. 156 and 157 represent two improved bipolar intra-uterine electrodes, the first with platinum olive and platinum-tipped flexible muff, and the other with plain platinum contacts, but in other respects similar to the bipolar electrode for the faradic current.

Interstitial or Metallic Electrolysis in Uterine Disease.—Interstitial electrolysis as systematized by Gautier * is a method of considerable interest, and although it may not and very likely will not fulfil the expectations of its author and of others who have written about it, yet some promising results have been reported.

By this method the chemic action of the positive pole is utilized, not

FIG. 152.—Intra-Uterine Electrode for Sectional Cauterization.

only for its effects upon the tissue itself, but upon the metal electrode—mainly copper or zinc, that are applied directly to, or inserted into, the diseased part.

In this way new salts are formed and deposited in the tissues, oxychloride of zinc when zinc, and oxychloride of copper when copper elec-

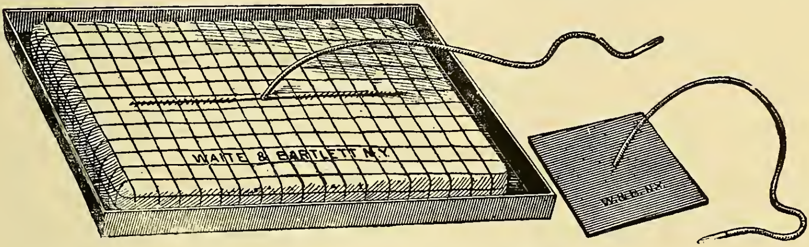

FIG. 153.—Apostoli's Abdominal Clay Electrodes.

trodes are used. It is the cataphoric property of the current, however, which carries or forces these salts, the product of electrolytic action,

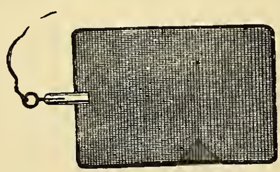

FIG. 154.—Flexible Metal Electrode.

through the surrounding tissues to a greater or less depth according to the strength of the current and length of treatment. As compared with the ordinary method of galvano-cauterization the experiments of Gautier on rabbits seemed to show that interstitial or metallic electrolysis with copper electrodes was the more efficient method in its microbicidal action.

Figs. 163 to 164 illustrate some of the electrodes used in interstitial electrolysis. The technique of this treatment is similar to that of the

* "Technique d'Electrothérapie," Revue Internationale d'Electrothérapie, July, 1893.

galvano-caustic treatment of the uterine organs, only it is to be remembered that while in the last method either pole may be indicated, in the other the positive is always the active pole. The strength of current generally to be recommended varies from 25 to 50 milliamperes, and the best

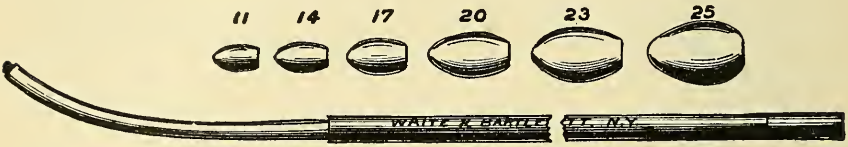

FIG. 155.—Fry's Intra-Uterine Electrode for Stenosis.

results seem to have been obtained in uterine hyperplasia, in tubal inflammations, and in pelvic exudations. Gautier reports excellent results also in diseased conditions of the endometrium where gonococci have been found. Intra-uterine applications by this method should be infrequent,

FIG. 156.—Bipolar Intra-Uterine Electrode for Galvanic Current.

not oftener than three or four times a month. Cleaves * reports results that have been retarded by too frequent applications.

Amenorrhœa.—In its relations to those three cardinal symptoms of deranged menstruation, amenorrhœa, dysmenorrhœa, and menorrhagia, elec-

FIG. 157.—Bipolar Intra-Uterine Electrode for Galvanic Current.

tricity was as capricious and paradoxical as it sometimes proved to be in its application to certain nervous derangements.

It would excite the menstrual flow when absent, decrease it when profuse, and temporarily and sometimes permanently relieve the pain that might be attendant upon these conditions, and then again in other cases would fail utterly to accomplish what previous experience had given us every reason to expect. Its action was a seeming paradox, in that it relieved diametrically opposite conditions, and was capricious because at one time it would relieve, and at another fail to do so.

As a matter of fact, however, the remedy is neither capricious nor paradoxical in its action.

* Transactions American Electro-Therapeutic Association, 1893.

It works in accordance with certain fixed laws, and its chemic activity is under such perfect control that it will perform for us the exact measure of work desired, so that now, with our better knowledge of its physics and

FIG. 15.8—Rockwell's Disc Clay Electrode, Front View (Kidder).

its physiology, and by the aid of correct current measurements and electrodes properly adapted, it is possible to obtain far better results in the

FIG. 159.—Disc Electrode, Rear View.

future than in the past. The seemingly capricious action of electricity then, in conditions of disordered menstruation, is in great measure due to our imperfect knowledge of the various factors that go to make up these morbid states, and as increasing knowledge enables us to fit more accurately the remedy to the disease, so shall we with greater certainty be able to differentiate between those menstrual derangements which can, and those which cannot, be cured by electricity.

In amenorrhœa electricity is more especially indicated in those cases

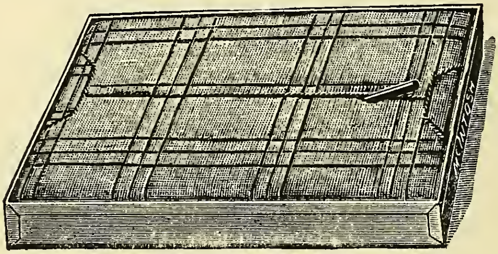

FIG. 160.—Abdominal Clay Electrode (McIntosh).

that are dependent on some constitutional cause associated with chlorosis, and upon imperfect development or atrophy of the organs of generation. It is needless to say that in chlorosis and anæmia, amenorrhœa is the natural condition, and efforts to force the menses by any form of local

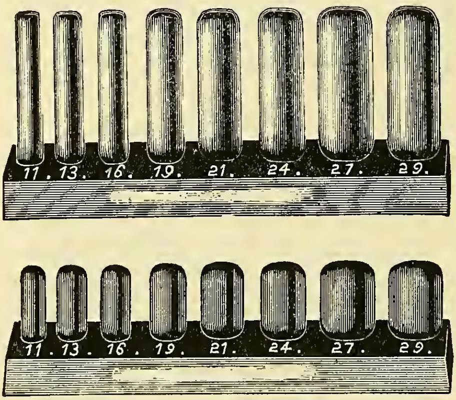

FIG. 161.—Soluble Metallic Bulbs for Interstitial Electrolysis (Van Houten & Ten Broeck).

treatment would be entirely out of place. On the contrary, when menstruation persists, along with a decided anæmic condition, the lining membrane of the uterus may itself be diseased, and call for local treatment for the purpose of stopping the flow. It is in amenorrhœa existing as a symptom of anæmia that electricity, through general and not local methods of application, is especially indicated. It is not to be used to the exclusion of iron and other tonics, but in conjunction with them. Treated in this way, cases of long-standing anæmia, with their associated symptom, amenorrhœa, will recover far more rapidly than when internal medication alone is relied upon. Great mistakes are committed in the treatment by electricity of amenorrhœa associated with anæmia, in applying the galvanic current directly to the uterus.

Localized galvanization is not indicated in these cases; on the con-

FIG. 162.

FIG. 163.—Handles with Soluble Bulb Attached.

FIG. 164.—Protected Uterine Sound of Soluble Metal. (Galvano-Faradic Mfg. Co.)

trary, as we have had abundant occasion to observe, it tends to induce a condition of nervous irritation that is exceedingly unpleasant. It is in these conditions of amenorrhœa, when the patient is weak and anæmic, with perhaps other indications of constitutional disturbance, that the faradic current is strongly indicated over the galvanic.

On the other hand, in those cases of amenorrhœa where the patients are robust and of full habit, the galvanic current is likely to be of far greater service than either the faradic current or franklinic electricity.

Another well-recognized cause of amenorrhœa is atrophy, as well as arrested development of the uterus. The well-known power of electricity to variously modify nutrition would indicate its use in these conditions; practically, we have found it to be efficacious in several cases, and see no reason why it should not always be of more or less service. In super-involution also it may be tried with expectation of success, provided there is evidence of active ovulation.

If there are no such evidences the probabilities are that neither electricity nor any other remedy will be of service.

Dr. Fordyce Barker has enumerated the following symptoms, at or near the menstrual period, as evidence of the existence of ovulation associated with super-involution: intense headache, flushing of the face and congestion of the eye, pelvic pain and sense of dragging, with nausea, vomiting, etc. It is interesting to note that in two cases of super-involution that we have successfully treated, all of these disturbing symptoms were present, and all disappeared with the return of menstruation. We may add that in these cases the condition followed a dangerous and difficult labor. For two years menstruation had appeared but once or twice, and upon measurement the uterus was found in each case to be but about one and three-fourths of an inch in length.

Dysmenorrhœa.—Speaking from no inconsiderable experience in the treatment of the disorders of menstruation, we confidently assert that the greater number of cases of dysmenorrhœa, taking the cases as we find them in ordinary practice, can be very much relieved by electricity, and many of them permanently cured. Obstruction to the free flow of blood must be regarded as the main cause of painful menstruation, and when this obstruction is due to mechanical causes, such as stenosis, the electrolytic method is to be used.

In the vast majority of cases, however, while there may be often found changes in the lining membrane of the uterus, there yet exists no serious structural change or mechanical obstruction. Whatever the condition of the endometrium which fails to allow the free flow of blood into the cavity of the uterus, thus causing distention and pressure, with pain of greater or less severity, the free and steady flow of the galvanic current through the uterine organs is most efficacious in relieving this congestion and preventing pain.

It should be applied just before menstruation, and repeated every day, if necessary, until the flow appears. In those cases where there is usually a long struggle and great delay, we have by these applications frequently caused the menses to appear promptly on time, and without the slightest suggestion of pain.

The faradic current will occasionally relieve dysmenorrhœa, but for obvious reasons it has no such influence over the condition as the galvanic current. Another cause of dysmenorrhœa, for the relief of which we have good reason to place great faith in the absorptive action of the galvanic current, is the pressure occasioned by the exudations following attacks of pelvic cellulitis. In these cases the treatment must often be prolonged, and months may be consumed in the efforts to dissolve the products of exudation, but the results that follow more than compensate for the time and trouble expended.

Menorrhagia.—The medical use of electricity has no such influence over excessive as it has over painful menstruation, although electrolytic treatment where uterine fibroids or polypi are the causes not infrequently effects most marvellous changes. We have, however, met cases of menorrhagia occurring toward the decline of sexual activity, where simple external applications by the method of general faradization have proven most effective measures of relief. These cases are generally associated with constipation, torpidity of the liver, and often with nervous exhaustion, and the indications are excellently met by the powerful constitutional effects of this most valuable method of treatment.

Chronic Pelvic Cellulitis.—In the sequelæ of pelvic cellulitis the application of the galvanic current is often followed by the most satisfactory results. For the absorption of old exudations in other parts of the body this form of electricity has long been known to be most efficacious, but only within a comparatively recent period has it been tested in the thickening and infiltration resulting from inflammation of the pelvic cellular tissue. The negative pole, consisting of a metal ball covered with absorbent cotton or fine sponge, is to be used internally, and directly to the part affected, while the positive is applied externally.

This treatment, judiciously and persistently carried out, with a current strength from 25 even to as high as 100 milliamperes has resulted not only in the absorption of large pelvic deposits, but in the cure of the most severe and obstinate sciatica, and in the restoration of power to paralyzed limbs. In su h cases both sciatica and paralysis are caused undoubtedly by pressure of the exudations upon the pelvic floor, and can be relieved only through the dissipation of the morbid products.

Fibroid Tumors.—It is in the treatment of fibroid tumors of the uterus by electrolysis that the new departure in regard to greatly increased strength of current is more especially applicable. If the tumor is in a position to be readily reached, there is no question of the propriety of resorting to electro-puncture, nor of its good effects, any more than there is of the results that may follow simple local galvanization. The difference between the two is, that local galvanization of the tumor is a slow and tedious method, occupying months to accomplish even a small reduction, while electro-puncture produces far greater effects in a much shorter space of time. It is almost incredible how many symptoms sometimes disappear after the very slightest reduction in the size of a fibroid tumor, or of an enlarged uterus, or of the products of inflammation, and for this reason the simpler, safer, and less disagreeable procedure is by no means to be despised, when for any reason whatever the other is not feasible. We have seen a good number of cases, where difficulty and pain on micturition, due to pressure on the neck of the bladder, rectal difficulties due to pressure there, dysmenorrhœa and menorrhagia, together with other pains, and impaired locomotion, have been either cured or greatly alleviated by simple local galvanization, which has only succeeded in dissipating a small fraction of the supposed cause of these symptoms.

Nor will electro-puncture, as a rule, entirely dissipate a fibroid tumor, although it will reduce it far more than the simpler method. But if it will not entirely dissipate it, it will so reduce it that it becomes quite harmless, and the patient is symptomatically cured.

In the treatment of fibroid tumors then, the following suggestions may rove of service. The first requisite, of course, is an apparatus with a sufficient number of cells, if there is no street current, needles for introduction into the tumor, and a proper external electrode. The second requisite is a milliammeter, with a registration of over a hundred, and at the same time, if possible, one that does not oscillate so persistently as those in common use.

Excepting in those cases where the object is to control hemorrhage, the needles should be attached to the negative pole, while the positive pole, for application over the abdomen, should consist of an electrode similar to those that have been already referred to.

This is placed upon the abdomen, and may be pressed upon and kept in position by the hand of the patient herself, if no assistant is present. The needle or needles are now introduced into the tumor, and the current gradually increased without interruption, until 100 to 250 milliamperes are reached.

The duration of the *séance* may be from five to ten minutes, and even longer, if the patient bears it well. Too much stress cannot be laid upon the necessity of an entire absence of any interruption of the current during the treatment. In trivial operations, where the tension is slight, this is not of such vital importance, but in the treatment of condition where a very great strength of current is necessary, a shock would decidedly disturb a patient of even strong nerve, and inflict serious damage on many. No one would willingly do this, but there are so many possible disturbing factors to the steady working of the current, that from personal knowledge of the condition in which physicians too frequently keep their electric apparatus and appliances, these interruptions are liable to occur at any moment, and when least expected or desired. It is to be doubted whether many patients would submit themselves to a second trial after having received a shock from a current strength of one hundred milliamperes.

While the treatment of fibroid tumors by electro-puncture is liable to be attended with more unpleasant results, it is no more efficient in many cases of uterine myomata than the more simple method of intra-uterine applications, and in our opinion the latter method should, as a rule, be attempted before resorting to puncture. If, indeed, in any case of intramural fibroid it is impossible to enter the cavity with our electrode, or when a sub-peritoneal tumor is so situated as to be beyond the effects of intra-uterine applications—in these emergencies, puncture is of course the only choice. Punctures may be made either through the vagina or abdomen. The former method is generally preferred. In hemorrhagic cases the positive pole is indicated, and it cannot be too often repeated that with this pole platinum or some other non-oxidizable electrode should always be used.

Ovarian Tumors.—The electrolytic treatment of ovarian tumors for a time excited much attention, but the success that attended these operations have been by no means satisfactory. The following *résumé** by Dr. Paul F. Mundé, made years ago, of what had been attempted and accomplished in this department of electro-surgery did much to discourage the operation, since it was evident that the results were not so good and the danger greater than the operation of ovariotomy.

He finds: 1st, "That a number of ovarian tumors, reported on reliable authority, have been completely cured or permanently improved by electrolysis—out of fifty-one cases, twenty-eight, or about 55 per cent.

2d, "In a number of these cases electrolysis was followed by dangerous (thirteen, or 25.4 per cent.) and even fatal results (nine out of these thirteen, or 17.6 per cent. of the whole fifty-one.

3d, "Further, six cases out of fifty-one received neither benefit nor injury from the treatment, and four were only temporarily improved; total, ten, or 19.6 per cent. We thus have a total of twenty-three cases, or 45 per cent., in which the electrolytic treatment failed to accomplish the object for which it was administered. . . .

6th, "Notwithstanding these undoubted cures, the percentage of successes of oöphoro-electrolysis (55 per cent.) compares unfavorably with that of ovariotomy (70 to 80 per cent.; Spencer Wells 78 per cent., in 1876 as high as 91 per cent.). And so also do the deaths by electrolysis (17.6 per cent.) nearly equal those following ovariotomy in recent years (20 to 30 per cent. to 22 per cent.), and far exceeding those occurring in the last series of fifty-five cases of Spencer Wells (five, or 9 per cent.)."

Chronic Metritis.—The value of intra-uterine applications of the galvanic current in the various stages of metritis has been so thoroughly tested as to be no longer a matter of doubt. The idea in these operations is to destroy the mucous membrane and produce a healthy derivation. The faradic current, which is so valuable in simple uterine engorgements following abortions and perhaps in the earlier stages of metritis, becomes useless in the presence of parenchymatous metritis. The chemic action of the galvanic current is alone serviceable in these cases. As in the treatment of fibroids, powerful currents are demanded, varying in strength from 50 to 150 milliamperes. Some good form of rheostat should be used, and as the current is gradually increased and decreased, the utmost care should be exercised to avoid shocks. The operation is not electrolysis proper, but more correctly a chemic galvano-cauterization. The choice of the intra-uterine pole will be determined by the symptoms in each individual case. At the positive pole, the acids and oxygen accumulate. This pole is therefore coagulating and hæmostatic, and is indicated in all forms of hemorrhages and abnormal discharges. Another advantage possessed by this in hemorrhagic conditions is due to the greater retractibility of the positive cicatrices which tend to prevent a return of the

* "The Value of Electrolysis in the Treatment of Ovarian Tumors," by Paul F. Mundé, M.D., New York, Gynecological Transactions, 1878.

hemorrhages. At the negative pole alkalies accumulate, producing some of the effects of caustic potash. It is sometimes called the fluidifying pole and is more especially indicated in the non-hemorrhagic forms of metritis. Beyond anything else it is the remedy for old, atrophic, or indurated forms of chronic metritis, where the conjunctive tissue has become hard, fibrous, and devoid of blood. Far more effectually than the positive pole, it excites the languid or perverted uterine circulation and restores the menstrual flow. The caution, never to use with the positive pole in intra-uterine applications any steel or other oxidizable electrode, cannot be too strongly emphasized.

Platinum is to be preferred, and although it is expensive it never wears out. A cheaper form of electrode is made of carbon, so thoroughly polished as to render it non-irritant, or of steel subjected to certain processes by hydrogen, which renders it non-oxidizable. In time, however, both of these materials become roughened through the constant action of the liberated oxygen.

Peri-Uterine Hæmatocele.—These tumors have been treated successfully by Apostoli by means of the chemic caustic action of the negative pole. A non-retractile fistula is thus made, the tendency of which is to remain open and with adhesions between the pathologic cavity and the external mucous membrane. The nutrition of these pathologic cavities is modified by the electrolytic action, and leads to rapid retrograde metamorphosis. The method is quick in its action, with claims for it of perfect safety.

Diseases of the Uterine Appendages.—In the various manifestations of disease of the uterine appendages—salpingitis, endosalpingitis, interstitial and suppurative salpingitis, pyosalpinx, hydro- and hæmatosalpinx, ovaritis, etc., electricity is often of much service.

In suppurative salpingitis Gautier * as well as Apostoli advises galvano-chemic cauterization with the negative pole in doses of 20 to 80 milliamperes. He says that the treatment favors the escape of pus into the uterine cavity, rapidly relieves congestion of the appendages, and quiets the pain. He, however, lays especial emphasis upon the necessity of great watchfulness and care in the treatment. If pain is increased, or the general condition in any way becomes worse, a collection of pus may be suspected and the treatment will be of no avail.

Uterine Hyperplasia.—In the treatment of this ordinarily intractable condition the persistent use of the galvanic current accomplishes much. Both intra- and extra-uterine applications may be used, but the latter are quite as efficient as the former, and less liable to produce unpleasant effects. By applying the electrode to the cervix, and as closely as possible to the body of the uterus, without entering the cavity, we do not indeed get as direct an effect as by intra-uterine applications, but this dis-

* "Revue International d'Electrothérapie," vol. ii., pp. 33–38.

advantage is more than balanced by the far greater strength of current that can be used. Electrolysis, however, is the most effective method. One or two needles may be thrust into the hardened tissues parallel to the canal, and a current of from 50 to 75 milliamperes used.

Stenosis of the Uterine Canal.—In stenosis of the uterine canal the action of the galvanic current is most valuable, and in many cases is sufficient to afford complete relief. A sound of the proper size (Fig. 155) having been introduced, it is connected with the negative pole, the positive being applied to the abdomen.

A strength of from 50 to 75 milliamperes, continued for five minutes, will, as a rule, be found sufficient.

Ovaralgia.—It is often most difficult to accurately localize intrapelvic pain, or to determine its cause, but we have in the induced current of tension and the bipolar method most effective remedies. Currents of quantity which act mainly on the motor nerves of the uterus and vagina simply increase the pain. The current of tension, however, with little power to induce uterine contractions, acts sometimes with almost magical effect in relieving the most severe intrapelvic pain.

Subinvolution and Atrophy.—Both subinvolution and atrophy of the uterus are amenable to treatment by electricity. In reference to the kind of electricity to be employed the galvanic current is undoubtedly indicated when the disease has passed into the second or inflammatory stage, and the method of treatment is such as is described in the management of chronic metritis. In the earlier stages of subinvolution, however, the peculiar mechanical effects of the faradic current are indicated, for the purpose of stimulating the circulation, contracting the muscular and vascular elements, and re-establishing the arrested retrograde metamorphosis. The applications should be made by means of the bipolar electrode, using currents of quantity as indicated in chapter on bipolar faradization.

Displacements of the Uterus.—The two most important factors that make up the value of electric applications in displacements are probably the hyperæmia, and especially the contraction of muscular fibre, that follow its use; and as the contraction of a muscle determines the amount of its nutrition, it follows that if a current of electricity is localized in a given point of the uterus, that part will contract, its nutrition be improved, and at the same time counteract any flexion in the opposite direction. As the effects we desire in these cases are mostly mechanical, the faradic current is the form of electricity indicated, and as in bipolar faradization, the induced currents of quantity are far more efficient in causing contractions than the currents of tension.

The simplest and least efficacious method is to introduce one electrode behind the os uteri, while the other is applied externally over either the pubes or sacrum. In prolapsus uteri, much benefit has often followed this method of treatment by the tone imparted to the relaxed vaginal walls.

A more effective localization of the current is accomplished by introducing one electrode into the uterus while the other is placed externally; but the most effective method is the internal use of both poles.

In cases of anteflexion (Fig. 165) one pole, the curve of its stem corresponding to that of the sacrum, is introduced into the rectum, up to the point nearest the posterior wall of the uterus. In this way the current is quite accurately localized in the posterior uterine walls, causing contraction, and improving nutrition.

In retroflexion (Fig. 166) the first electrode, instead of being passed

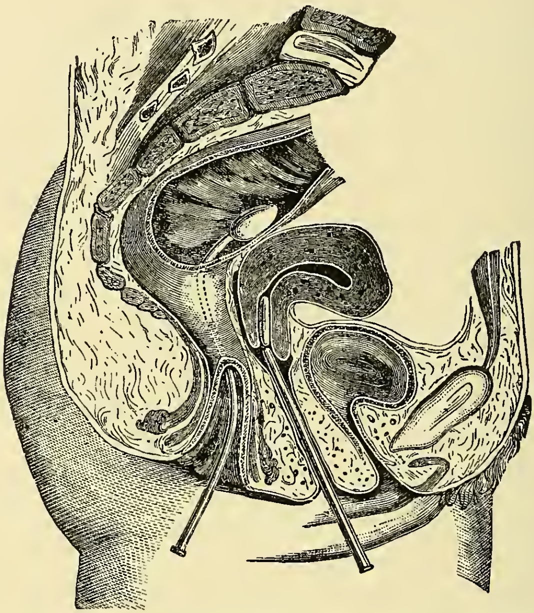

FIG. 165.—Anteflexion of the Uterus. Recto-Uterine Faradization.

into the rectum, is introduced into the bladder, and applied to the anterior wall of the uterus. When the faradic current is used, and this form is chiefly indicated, the relative position of the poles would seem to be of no special importance, although for the intra-uterine electrode the anode would seem to be preferable, on the theory that it has a greater power over unstriped muscular fibre. In these applications the pain is sometimes considerable, and is due to two causes: first, the concentrated action of the electricity on the mucous membrane; second the contraction of the uterine fibres. In other cases, very little discomfort is produced. By beginning with a very weak current, and gradually increasing it, a much greater strength can be endured than if this precaution is not observed.

When voluntary muscles are subjected to the action of the poles of either a galvanic or faradic battery contractions instantly occur.

These contractions continue, as is well known, during the passage of the faradic current, but quickly relax after the first shock of the galvanic. When, on the contrary, involuntary muscular fibres, of which the uterus is composed, are subjected to the influence of the electric current, movements are not induced until a certain time after the tissues have been acted upon. The movements thus excited continue for a time after the

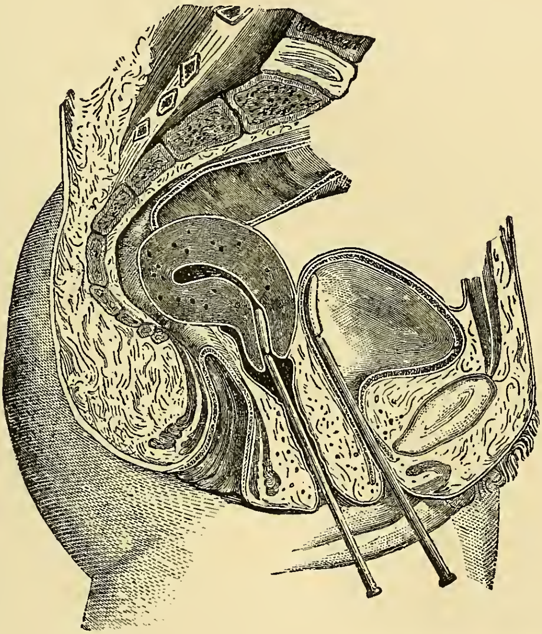

FIG. 166.—Retroflexion of the Uterus. Vesico-Uterine Faradization.

cessation of the current, and do not, as in the case of voluntary muscles, cease as soon as the electrodes are removed.

The following suggestions of Apostoli * upon the general intra-uterine use of the galvanic current are wise and based upon a great experience:

"Never apply in the first *séance* a strength greater than 50 milliamperes, and never, at first, exceed the dose tolerated by the uterus. Make the first galvanization slowly, with circumspection and gentleness. At once interrupt the *séance* as soon as there are any manifestations of intolerance, and renew it in two or three days when all reaction has subsided. Do not increase the intensity of the current or the length of the *séance*,

* Journal de Médecine, Paris, November 20th, 1892.

except in proportion to the degree of tolerance manifested in the preceding *séances*.

"These applications being well tolerated, if it is possible without causing operative reaction, and especially post-operative reaction, to increase the strength to 100 or 150 milliamperes, the appendages are in good condition, or, at least, they are not the seat of actual inflammation or suppuration. When the initial intolerance of the uterus grows less with the number of applications, the symptomatic amelioration being also marked and increasing with time, the case is hysterical or else the disease of the appendages is diminished or arrested.

"If, on the contrary, the galvanizations, in spite of the precautions indicated, with a current of 50, 30 or 20 milliamperes, awaken great susceptibility; if they be followed by painful or febrile reaction the following day or days; if this intolerance for the weakest current develop and increase with each *séance*, though these are repeated with moderation and prudence—then the uterine periphery is the seat of a lesion not amenable to conservative gynecology. All galvanic treatment should be suspended, and the patient advised to undergo an operation."

CHAPTER XXVI.

DISEASES OF THE GENITO-URINARY ORGANS.

THE medical diseases of the male genital organs, for which electricity is chiefly indicated, are spermatorrhœa, seminal emissions, impotence, incontinence of urine, paralysis of the bladder, chronic prostatitis, and enuresis.

As it has been doubted whether the resources of the electro-therapeutics are capable of affording any decided and lasting benefit in these diseases, we here record not only as the result of our own experience, but from a knowledge of the experience of others, that no case in which there have been reasonable grounds for hope can be said to have been fairly treated, until the proper application of electricity has been attempted.

It should be remarked that of spermatorrhœa, seminal emissions, and impotence, the latter, taking the cases as we find them, in young men is for the most part psychic and temporary in character—frequently associated with neurasthenic symptoms, and yields the most uniformly and readily to electric treatment. These three conditions are, however, very frequently associated, and the symptoms of each may be so intermingled as to render it difficult to decide which presents the most prominent indications.

Spermatorrhœa.—There can be no question that true spermatorrhœa is much less frequent than is generally believed. It consists of an involuntary discharge of semen without erection, and as there are several secretory glands besides the testicles, the secretion from which lubricates the urethral canal, and may even appear externally in a healthy condition of the parts, the activity of charlatans has had a fair field in which to excite alarm among the credulous.

Seminal emissions consist in an involuntary discharge of seminal fluid with erection, and demands treatment only when it becomes excessive, and is associated with, is dependent on, or is the cause of constitutional disturbance.

Treatment.—In regard to the treatment of spermatorrhœa and seminal emissions, it is hardly necessary to say that no one method of electrization will answer in all cases. The applications may be localized externally or internally, and in addition we frequently use with advantage general faradization and central galvanization. There is one method of procedure concerning the ill effects of which we have positive convictions.

We refer to strong galvanization of the ejaculatory ducts, or the parts in their immediate vicinity, by means of the insulated catheter electrode.

It is true that if employed with great caution, and with a current of very feeble power, no harm may result. Currents of considerable electrolytic power even may frequently be borne without any after ill effects; but it is equally true that these same applications, whether weak or strong, have in numbers of instances been followed by profound and lasting irritation.

Deaths have been known to result from the effects of the *porte caustique.* From the history of one of our cases, it seemed sufficiently clear that this treatment had laid the foundation of an obstinate stricture, and in another case of complete destruction of the virile power it was evident that the symptoms were in a measure due to a most severe and ill-advised cauterization of the ejaculatory ducts.

Electrolytic action is of course more completely under control, and although its action is different from that of the caustic, it is yet occasionally followed by substantially the same results, and we hesitate to make use of it in the irritable conditions that we are considering.

In lieu of this procedure, however, and in addition to the external methods of treatment, we are highly in favor of the direct application of the faradic current to the urethra, and on the same principles, and to meet the same indications, that the occasional introduction of the ordinary catheter is attempted. Mechanical pressure alone tends to unload the congested capillaries, and to very decidedly lessen the sensibility of the urethral nerves, and when combined with the vibratory action of the faradic current, we are convinced that its good effects are markedly increased.

Impotence.—The mildest and most frequent form of impotence manifests itself by a premature ejaculation of semen, with no special diminution of sexual desire, but with some impairment of the power of erection. A somewhat more persistent condition is shown by an appreciable diminution or capriciousness of the sexual appetite, with a marked decrease of the power of erection, and again there is not unfrequently an entire absence of sexual desire and power of erection. Another form of impotence may be termed psychic. The unfortunate subjects of this condition, ignorant of what the normal sexual appetite should be, oftentimes suppose that in their case it is deficient. Depressed and distracted by self-brooding, they sometimes fulfil their own dark forebodings, and fail in their preliminary attempts to accomplish the sexual act through the very intensity of their desire.

We shall not attempt to enter into any consideration of the causation of these symptoms, further than to say that the vast majority of cases of this character are brought on by the same general causes, masturbation, or suddenly breaking off the habit of masturbation, excessive sexual indulgence, prolonged continence, or by any influence that debilitates the system.

Not only in its incipient but in its more advanced stages, impotence not unfrequently is the result of organic disease of the nerve-centres, and its treatment by electricity is of importance only so far as it serves as an illustration of the extraordinary stimulating or tonic influence of the remedy. We have had patients suffering from incurable chronic hemiplegia, progressive muscular atrophy, locomotor ataxia, etc., where there has been, under local and general electrization, a most extraordinary increase in the desire and capacity for sexual intercourse.

Electro-Diagnosis.—Anæsthesia of one-half, usually the left, of the penis, is a condition not unfrequently observed in diseases of these parts. This may be detected by an electric examination or by the æsthesiometer. This peculiarity, which was first pointed out by Schulz, we have observed in a number of instances. With anæsthesia there may be coldness and blueness of the sexual organs.

Occasionally the anæsthesia is quite profound, and as a rule the sexual weakness is in proportion to the degree of the anæsthesia.

The numbness in these cases is more than an accidental association; it would indeed appear as if it were, to a certain extent, a cause; for by the application of the ordinary electric brush to the parts in the same way that we treat any case of local anæsthesia, the numbness is often removed, and the integrity of the sexual function restored.

Hyperæsthesia of the urethra is a condition that is sometimes observed, especially in patients otherwise nervous and irritable.

In the worst stages there may be atrophy of the testicles and the penis, and a diminution of temperature that is at once perceptible to the hand.

Treatment.—In the consideration of the various degrees of impaired sexual power, the question at once arises, What are the indications, and how are these indications to be fulfilled? In the milder forms of impotence, where there is simply premature ejaculation of semen, with some diminution of the power of erection, as well in the more advanced stages, where the desire is capricious and the power of erection pretty well destroyed, it is evident that there must be a degree of paralysis at the root of the disorder, dependent on structural changes in the nerve-centres, or else this impaired power or tone in the muscles and erectile tissue may be of a purely local character. In the latter case, the indications are clearly the same as in other forms of local paralysis, and by faradization of the ischio-cavernosus and bulbo-cavernosus muscles much may be accomplished. In recent cases of impotence, where there is considerable power remaining, as well as in a more advanced stage, where the power is approximately lost, we not unfrequently find that the seminal secretion is markedly reduced, not only in quantity but quality; and, reasoning from analogy, it would seem that in such cases there were undoubted indications for the use of electricity.

The galvanic current especially has the power of exciting to increased activity the secretory function of various glands, and not seldom accelerates physiologic mucous discharges. The salivary and lachrymal glands, as well as the liver, are susceptible to stimulation by electrization, and it is undoubtedly true that the lacteal secretion has been augmented by passing the current through the breasts of nursing women. (See chapter on Nutrition in Electro-Physiology.)

It is highly probable, then, that a deficiency in the secretion of semen when it is dependent on local paralysis or exhaustion of the nerves controlling this function, and not on pathologic changes of a structural character, may be successfully remedied by galvanizing the spermatic nerves and testicles. We cannot, however, in all cases, depend on local treatment alone. Not only may impotence be associated with, but it may result wholly from, disorders of a general character. The excessive use of sedative narcotic remedies, sedentary habits, and general malnutrition from any cause, lead to the condition under consideration, and demand the general constitutional tonic influence of general faradization or the powerful stimulating effects of static electrification.

The vesiculæ seminales and the testicles may be affected, and in some patients very powerfully and sensibly, when one of the poles is applied to the lower part of the spine, and the other to some point on the thigh or against the perineum. A very good way to affect the male reproductive organs is to apply one pole firmly against the perineum, or between the scrotum and penis, and the other on the spine over the genito-spinal centre.

Faradization of the genital organs should not usually be protracted longer than five to ten minutes; galvanization from two to eight minutes. The faradic current would appear to be preferable. Impotence, like seminal emissions, may sometimes be treated by connecting the steel sound introduced into the urethra with one of the poles of the faradic current, thus combining the toning effect of pressure with the toning effect of electricity on the relaxed parts.

Aspermatism.—Impotence, as before remarked, may manifest itself by many symptoms, and in various degrees; but there is one phase of it that is, we believe, not very common. It consists in an inability to ejaculate semen while the power of erection remains vigorous, and to this condition the term aspermatism was first proposed by Roubaud in 1855.

Dr. William H. Van Buren, in an article published in the New York *Medical Journal* for November, 1868, suggested that the difficulty in ejaculating the semen was caused by an exaggerated spasmodic contraction of the muscular fibres of the walls of the ejaculatory ducts, leading to their occlusion under extreme excitement. On this theory it would seem that the indications called for galvanization of the ejaculatory ducts; but in several cases that have come under our observation, and that might fairly

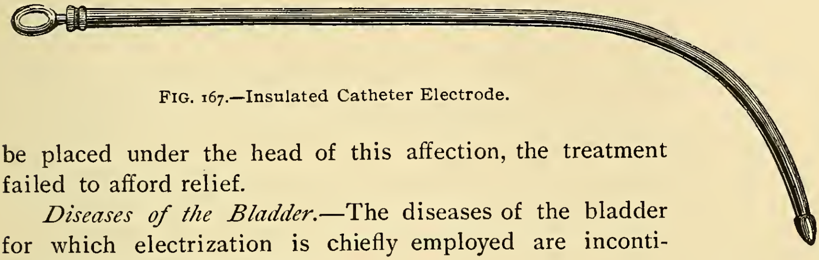

FIG. 167.—Insulated Catheter Electrode.

be placed under the head of this affection, the treatment failed to afford relief.

Diseases of the Bladder.—The diseases of the bladder for which electrization is chiefly employed are incontinence of urine and paralysis.

Incontinence of urine depends on an irritable condition of the neck of the bladder. While it largely sympathizes with other diseases and the general health, being frequently associated with hysteria and spinal irritation, it is yet oftentimes a purely local affection. There are various grades of the disease, from simple irritability that makes it necessary to pass the water with unusual frequency, to utter inability to sleep through the night without unconsciously "wetting the bed." The former condition exists mostly in adults—especially in the hysterical and the aged; the latter is peculiar to the period of childhood. It is probable that the pathologic condition in children who nightly void their urine in bed is not necessarily worse than that in adults who only complain of being obliged to pass the water with abnormal frequency. The unpleasant results in children are due to their profound sleep or deficient self-control. That the pathologic condition in children is not always of an important character is proved by the fact that it sometimes yields to purely moral influences.

In the treatment of incontinence of urine, both external and internal

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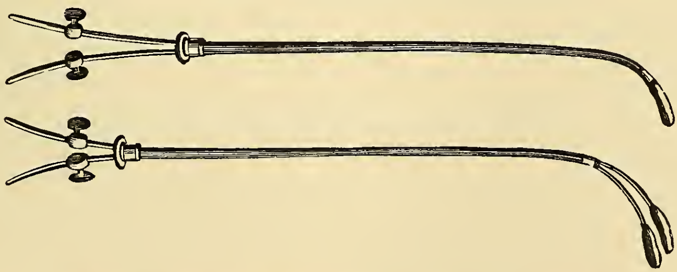


FIGS. 168, 169.—Double Vesical Exciter or Electrode (Duchenne).

applications may be used. In the majority of cases the internal applications by means of the catheter electrode are not required. It is needless to say that in young children the introduction of the catheter electrode is attended with difficulty. The treatment we prefer is faradization with strong currents through the neck of the bladder. In males one pole may be placed over the symphysis pubis, and the other at the perineum; in females one pole may be applied over the symphysis pubis and the other at the lower part of the sacrum. Cases associated with hysteria, or dependent on spinal disease, need central and general electrization. Danion,* of Paris, has made a report on the utility of electro-therapy in diverse forms of incontinence of urine to the sixth French congress of surgery. His observations were nine in number, leaving out those on nocturnal incontinence in children. The treatment consisted in the application of the faradic current by shock and tetanization to the neck and membranous portion of the urethra. The effects were proved by Guyon and himself to be not only favorable and rapid, but sometimes really remarkable.

Prognosis.—The prognosis of young and recent cases is usually good. Long-standing cases also yield, but need correspondingly longer treatment, and are liable to relapse. Cases complicated with constitutional or central disease, which are, of course, mostly found in adults, have either a favorable or unfavorable prognosis, according to the nature of the malady with which they are complicated.

Enuresis and Strangury.—Grimm,† of Vienna, reports excellent results in enuresis from faulty innervation and not due to urethral or bladder disease—one electrode is placed in the rectum, the other on the thigh with a current strength of two to five milliamperes. The application should be from five to ten minutes each night before retiring. Benedikt,‡ of Vienna, reports two cases of strangury that were quickly relieved by applying the electrostatic douche and sparks to the spine and hypogastrium. Previous treatment had failed to ameliorate. The first case was tabes of long duration, strangury being the most distressing symptom. Relief was increased by each application.

In the second case the affection followed an operation for hemorrhoids many years before. Immediately after the first sitting the number of nocturnal micturitions sank from twenty-five to nine. More recent successful cases led him to regard this treatment as a specific.

Paresis § *and Paralysis.*—Paresis and paralysis of the bladder so frequently depend on incurable diseases of the spine, that the prognosis is, as a rule, unfavorable as regards a complete cure. Relief and improvement, even in very bad cases, may be gained by faithful treatment, but entire recoveries are exceptional.

* La Semaine Médicale, Paris, April 30th, 1893.

† Internationale klinische Rundschau, Vienna, February 29th, 1893.

‡ Wiener medizinische Presse, Vienna, November 29th, 1891.

§ From *παρεσις*, exhaustion.

The treatment should be external and internal, with both the galvanic and faradic currents, combined with central galvanization.

External applications may be made, placing one pole, the negative, over the symphysis pubis, and the other on the back, or at the nape of the neck, and passing very strong faradic currents with interruptions.

Internal applications may be made either with the insulated catheter electrode, or with Duchenne's double vesical electrode (Figs. 168, 169).

The catheter electrode may be connected with the negative pole while the positive is at the hypogastric region or back. By means of the double exciter of Duchenne the current can be more exclusively localized in the muscles of the bladder than by any other method.

Gonorrhœa.—It would not be unreasonable to suppose that gonorrhœa in its subacute stage might be treated by electrization with at least as satisfactory results as are subacute inflammations of the mucous membrane.

We have had opportunity to test both faradization and galvanization in several cases and with some suggestive results.

Chronic urethritis (gleet) we have treated by mild galvanization, 5 to 10 milliamperes, with the catheter electrode and sounds, and with encouraging results. Electricity thus used acts well as an adjuvant to the other treatment, just as in catarrh of the nose, granular lids, chronic inflammation of the middle ear, and analogous conditions.

Gautier * has shown that both poles of the galvanic current have a germicidal action, and proposes making use of this in the treatment of gonorrhœa in the female. Prochownick, in order to use the positive pole of his galvanic battery, used a copper sound of convenient size which he introduced into the cervical canal. This was connected with the positive pole and an intensity of 80 to 100 milliamperes was used for ten minutes. Three to six sittings were given. The gonococci disappeared and the purulent discharge became serous. In applications of the kind, chlorine is given off and copper sounds become covered with the chloride of copper, which is a highly antiseptic salt. Another method of procedure from which Gautier claims excellent results is to cover a platinum sound with a light layer of absorbent cotton which is plunged into a solution of iodide of potassium. In the urethra the positive pole is used with a current of 25 milliamperes; in the cervical canal the negative pole with a current of 50 milliamperes.

Syphilis.—The severe pains of secondary syphilis are to a certain extent relievable by general and localized faradization, as we have demonstrated in a few instances; concerning the permanency of their effects we have as yet no positive evidence.

(For the treatment of syphilitic ulcers, see Ulcers.)

* Archives of Gynæcology, 1894.

Buboes may be discussed by external faradization, and have been so treated by Hassenstein.* Chovstek has used galvanization.

Orchitis.—The electric treatment of orchitis has been particularly studied by Drs. Jules Chéron and Moreau-Wolf.†

They give the results of the treatment in nine successful cases. Their method of treatment was to direct a galvanic current from ten to twenty-four cells of Remak, through the tumor, from two to eight minutes. Sometimes the positive pole was placed on the most painful point of the swelling, and the negative on the spermatic cord. The authors regard the ascending current (up the cord) more effective than the descending.

Most of their cases were cured by a few (from four to ten) applications.

The great advantage which the authors claim for this method of treatment in orchitis is, that the patient is not obliged to suspend his daily duties, since absolute repose is not necessary.

Enlargement of the Prostate.—The electric treatment of hypertrophy of the prostate has been studied by Tripier,‡ Newman, and others, who claim to have demonstrated that the effect of faradization of this organ when enlarged is to cause resolution. The rationale of the treatment is substantially the same as for analogous conditions of the uterus. The subject is one that deserves investigation. Either the galvanic or the faradic current may be employed. One pole may be applied internally by means of an insulated catheter electrode or sound, and the other in the rectum against the prostate, by means of a rectal electrode. We have treated several cases of enlarged prostate by internal and external faradization. One patient, a medical gentleman about sixty years of age, was seen and examined by Dr. Gouley, who confirmed the diagnosis of enlarged prostate. We treated him a number of times by external faradization—one pole on the symphysis pubis and the other on the perinæum—and by internal faradization, one pole in the rectum—insulated except at the point where it came near the prostate—and the connection made in the prostate portion of the urethra by a flexible sound, passed through a gum-elastic catheter, according to the suggestion of Dr. Gouley. Applied in this way the electrodes were very near to each other and in sensitive localities, and only very feeble currents could be borne, and sometimes slight hemorrhage followed the treatment in spite of all the caution that was exercised. It was found impossible to use sufficiently strong currents by this method to produce any effect, and again we returned to partly external faradization. This treatment, which seemed to aggravate a cystitis that existed, was abandoned.

* "Chemisch-electrische Heilwerke," Leipzig, 1853.

† "Du Traitement de l'Orchite, par l'application des courants continus constants," Paris, 1869.

‡ "Manuel d'Électrothérapie," p. 567.

Dr. Mittendorf, of this city, informs us that he has obtained decided results in enlargement of the prostate, in two cases. He used external faradization—one pole over the symphysis pubis and the other at the perinæum.

In chronic prostatitis Dr. G. B. Massey * reports good results from the following method: An olive-shaped electrode, about the size of the index finger, mounted on an insulated staff, is introduced into the rectum and pressed against the under surface of the gland. The indifferent pole is placed upon the abdomen. The effects of currents of from 40 to 60 milliamperes, applications of short duration, are but slightly unpleasant, and their power to cause absorption of effused and adventitious material and promote healthful contractions of unstriped muscle is very great. By the conjoint use of the primary, or coarse wire secondary, faradic current the shrinkage is further promoted.

If the active electrode is carried a little higher—and this is facilitated by its being hollow and serving to introduce a cushion of water before it from a syringe—it is a powerful stimulant to an atonic bladder, so often associated with prostatitis.

* Journal of Electro-Therapeutics, July, 1894.

CHAPTER XXVII.

DISEASES OF THE LARYNX, NASAL CAVITIES, AND PHARYNX.

Anæmia and Inflammation.—External electrization of the throat is of service as an adjunct in the treatment of inflamed and irritable conditions of the larynx. We have found that faradization of the neck, for from two to five minutes, has an appreciable and agreeable effect in diminishing the irritation produced by cauterization, and when continued exerts a tonic influence on the organ. In cases of diseases of the larynx, connected with hysteria or anæmia, the local treatment is materially aided by general faradization.

Subacute and chronic inflammations of the pharynx are also treated with some success in the same way, and on the same principles.

Method of External Electrization.—The larynx may be electrized externally by various positions of the electrodes. One pole may be placed at the back of the neck and the other just above the manubrium sterni, or the poles may be pressed against the larynx by the inner border of the sterno-cleido-mastoid muscle, or one of the poles may be in the hand of the patient. These methods are best adapted for the purposes of producing a sedative or tonic effect on the inflamed and irritated membranes. We have frequently used this treatment, for about five minutes after the application to the larynx of irritating caustics, with satisfactory results. There is no question that the faradic current, employed perseveringly by these methods, and in cases of anæmia and general debility, by general electrization, will alone accomplish something in anæmia, subacute inflammations, and nervous debility of the larynx.

Aphonia.—Electricity is not infrequently of the greatest service in aphonia. In order, however, to form a correct idea of its value in these cases, or to intelligently communicate the results of electric treatment, it is necessary to have not only a knowledge of the general nature of the disease, but to appreciate, so far as possible, the exact pathologic condition of each individual case. Above all, it is necessary to decide whether the symptom is of an organic or of the so-called functional character. Mackenzie, who in his time had an extended experience in nervous affections of the larynx, and their treatment by electrization and otherwise, adopted the following nomenclature of the paralyses of the muscles acting on the vocal cords: *

* "On the Laryngoscope," etc., p. 183. Also "Hoarseness, Loss of Voice, and Stridulous Breathing, in Relation to Nervo-Muscular Affections of the Larynx."

1. Bilateral paralysis of the adductors.
2. Unilateral paralysis of the adductors.
3. Bilateral paralysis of the abductors.
4. Unilateral paralysis of an abductor.
5. Paralysis of the tensors.
6. Paralysis of the laxors.

The first of the above-mentioned pathologic conditions of aphonia is supposed to depend most frequently upon hysteria and debility, and readily yields to treatment. In these cases, however, which are too frequently but the local manifestation of a constitutional disorder, it has been our custom to rely on general as well as localized electrization.

Central difficulty is rarely a cause of bilateral paralysis of the adductors, but it is not uncommon in certain stages of phthisis. In 37 cases of phthisis, examined by Mackenzie, in which the voice was affected, he found that in 26 there was thickening or congestion of the mucous membrane of the larynx, while in 11 the affection was purely functional. Aphonia, then, coexisting with pulmonary tuberculosis, may often be readily relieved by local treatment alone.

Hysteria and debility are not so frequently the cause of unilateral paralysis of the adductors as of the first-named condition. This second cause of aphonia, however, may be due not only to phthisis, but to toxæmic poisoning, to syphilis, to cold, to muscular strain, and even to cerebral disease. We would naturally infer that this form of aphonia would be more persistent than the first-named.

Clinical experience has confirmed this inference.

Bilateral paralysis of the abductors of the vocal cords has, unfortunately, for its causation, in the majority of cases, some central difficulty.

The prognosis is of course most serious, but fortunately this condition is very rarely met with. Unilateral paralysis of an abductor, although depending on the same general cause as the bilateral form, yet, more frequently than the last-named, it is excited by some peripheral irritation, as pressure on the pneumogastric nerve, or upon one recurrent nerve, by an aneurism of the arch of the aorta. The prognosis in these cases is also unfavorable.

Paralysis of the tensors and laxors (both the bilateral and unilateral form) are supposed to result, in the majority of cases, from a too prolonged or violent use of the voice. Both are said to be quite amenable to treatment.

Spasm of the muscles controlling the vocal cords is an additional cause of aphonia.

Treatment.—Mackenzie's method was to make the application directly to the cords by means of laryngeal electrodes devised by him. He used the faradic current.

The direct application of electricity to the vocal cords is undoubtedly more efficacious in restoring loss of voice than simple external application. This latter method is, however, underrated when it is said that it "seldom restores the voice when it has been lost any length of time." Several cases that we have treated at various times illustrate very decidedly the beneficial results that may follow external applications, even in cases where the disorder has persisted several months. We are the more gratified to be able to make this statement from the fact that the external is much more readily performed by the operator than the internal application, and is far more agreeable to the patient. It is far better at first, in all ordinary cases, to make use of the external method, and if it does not succeed, it is time enough to resort to the direct application. The instrument of Mackenzie is thus described in his own words:

"It consists of two parts, viz., the necklet, which the patient wears, and to which one chain of the battery is attached, and the laryngeal electrode itself, which is connected with the other conductor. The electrode is so constructed (Fig. 170) that the current does not pass beyond a certain point until the pole is seen in the laryngeal mirror to be upon the vocal cords, when the operator touches a little spring in the handle, and the current immediately passes through the laryngeal muscles. The necklet should be worn rather low, so that it covers the sides of the cricoid cartilage, and the space between it and the thyroid. In this way the lateral adductors of the cords (crico-arytenoidei laterales) can be most easily reached; and the arytenoideus proprius, or central adductor, may be electrified by placing the pole on the posterior surface of the arytenoid cartilages.

"I generally keep the pole in the larynx for three or four seconds each time it is introduced, and pass a succession of short, rapid shocks through the larynx; and at each sitting I apply the pole to the interior of the larynx three or four times."

Mackenzie was of the opinion that the effects are of a reflex as well as direct character.

Meyer * reports successful results in the treatment especially of hysterical aphonia by the electric moxa, applied to the larynx.

Some of his cases were cured by a single application; in others a course of treatment was required. Tobold speaks favorably of the electric moxa in hysterical aphonia. It should be borne in mind that in hysterical aphonia any form of irritation, external or internal, electric or otherwise, may cause instantaneous cure. Some of the most brilliant achievements of mesmerizers and of those who practise laying on of hands and other flummeries, have been made in hysterical aphonia.

Kind of Current to be Employed.—For electrization of the larynx, externally and internally, both currents have been used with success.

* Op. cit., p. 436 et seq.

Irritation of the Muscles of the Larynx.*

Crico-Thyroid.—This muscle may be caused to contract by applying pointed electrodes by the conoidal ligament. The effect of the contraction is to cause the annular and thyroid cartilages to approach each other.

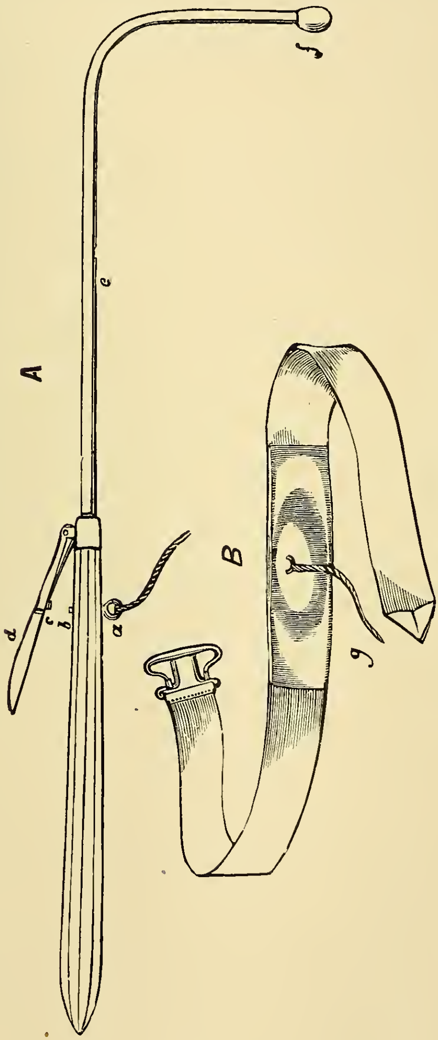


FIG. 170.—Laryngeal Electrode and Necklet.

A represents the electrode (No. 1). The instrument is connected with the electric apparatus by the connecting wire at *a*. When the insulated handle is pressed upon, the circuit is closed by the junction of *c* and *b*, and the current passes to the metallic point *f*. The wire *e* and the handle of the electrode are insulated. *B* is the necklet.

Mackenzie has also devised another form (No. 2) of electrode, in which the two poles are united in the same instrument, after the manner of Duchenne's double vertical electrode.

Arytenoid Transverse, at the posterior surface of the arytenoid carti-

* The subject of direct electrization of the laryngeal muscles has been studied by Ziemssen, "Elektricität in der Medicin," 1866.

lages. The effect of the contraction of the muscles is to cause the cartilages to approach each other.

Crico-arytenoid and Thyro-arytenoid Muscles, in the sinus pyriformis, between the posterior border of the thyroid cartilages and the plate or surface of the cricoid cartilages.

Crico-arytenoid Posterior (dilator of the glottis), downward and backward from the sinus pyriformis.

Crico-arytenoid Lateralis, in the sinus pyriformis on the exterior border of the surface of the annular cartilage. Contraction of these muscles produces rotation of the cartilages of the larynx, with movement of the vocal cord toward the median line.

Thyro-arytenoid, beneath the anterior superior border of the crico-arytenoideus lateralis. Contraction of this muscle brings the cartilages of the larynx forward and downward, and narrows the glottis.

Thyro-epiglottic and Ary-epiglottic Muscles, at the border of the epiglottis.

Prognosis in Aphonia.—The prognosis in aphonia depends entirely on the pathology. In functional (bilateral paralysis of the adductors) aphonia the prognosis is more favorable than in almost any other disease that is known to science. The majority of cases will recover, whether external or internal applications are used, although Mackenzie contended that the recovery is much surer and speedier than when only internal applications are used. He said, out of more than two hundred such cases he had succeeded in all except four. In some of these cases the aphonia was of six, seven, and even eight years' standing.

In unilateral paralysis of the adductors the prognosis is good when the origin is local, and bad when it is central.

In bilateral paralysis of the abductors and unilateral paralysis of the abductor the prognosis is unfavorable.

In paralysis of the tensors of the vocal cord the prognosis is usually favorable.

In paralysis of the laxors of the vocal cord the prognosis is on the whole favorable, but much time is required.

Spasmus Glottidis (*Laryngismus Stridulus—Spasm of the Glottis*).—In this affection, which is acknowledged to be of a nervous character, electric treatment is indicated on the same principles on which it is indicated in torticollis, writer's cramp, and facial spasm.

The disease is caused by any influences that depress the system. In children it may arise by reflex action from the irritation of teething or of worms; in adults it is often an accompaniment of hysteria, and arises from diseases of the sexual organs.

Treatment.—General faradization and galvanization of the sympathetic, and external galvanization and faradization of the larynx by any of the methods previously described.

Tobold reports success with peripheral and central galvanization in this disease. A strong maiden, 23 years of age, who was attacked regularly every night with severe spasms of the larynx, was entirely cured in four weeks by galvanization.

Nervous Cough.—Electric treatment is sometimes excellent for nervous coughs of various kinds. External faradization or galvanization or central galvanization are indicated. The treatment most beneficial in our own experience is the direct application of the galvanic current, 15 to 20 milliamperes. One pole, the anode, to the back of neck—the other to the throat.

Anæsthesia and Hyperæsthesia of the Larynx.—Anæsthesia is an affection but rarely observed. It would be most likely to occur from injury of the pneumogastric nerves of their laryngeal branches.

It is rational to suppose that anæsthesia of the larynx might be successfully treated by electrization in its various forms, on the same principle as that this morbid condition is treated in other parts of the body. Cases of hyperæsthesia of the larynx have been reported by Gerhardt and Hanfield Jones. In one case that came under our own observation no result followed electric treatment.

Atrophic Rhinitis.—The galvanic current is of value in this condition. Delavan,* of New York, who has had much experience in its use, applies the negative pole to the retronasal space, positive to the nape of the neck, using a current of 4 to 7 milliamperes from five to twelve minutes. He reports favorable results.

Out of 21 cases Hartman † reported favorable results in 14.

In hypertrophic rhinitis, both Delavan and Leute find the application of the galvanic current decidedly beneficial.

Atrophic Pharyngitis.—Equally good results have been reported in the treatment of this condition. Shurly ‡ uses cocaine and then applies one electrode through the nasal passage, and the other to the posterior and lateral wall of the pharynx. The action of the c rrent increases both the secretion and color of the membrane. Sajous has observed good results in a case where the faradic current was used.

Anosmia, or Loss of Smell.—A frequent result of long-continued rhinitis is partial or complete anosmia. The acute form that appears in the early stages of severe cold usually passes away without treatment on the subsidence of the inflammation. In some cases anosmia is supposed to, and probably does, result from careless and too prolonged use of over-irritating injections. There are various grades of the disease, from simple and scarcely perceptible obtuseness of the smell to absolute inability to detect any odor whatever. Kerosene, coffee, illuminating gas, make no more impression than substances of a negative character.

* Transactions of the American Laryngological Association, 1887, p. 146.

† Ibid., 1888, p. 84, ‡ Ibid., 1885, p. 1.

Anosmia may also result from central as well as peripheral lesion.

The *treatment* of anosmia may be both external and internal. The external treatment is the same as that recommended for rhinitis, except that the current should be much stronger; the internal treatment consists in the direct application of a metallic electrode to the mucous membrane of the nasal passages. We have used for this purpose an insulated electrode, with a metallic bulbous extremity that can be run some distance up the inferior meatus. An insulated Eustachian catheter, containing a wire with a bulbous extremity, serves very well the purpose, or a common silver catheter, uninsulated, may be used; or, indeed, any flexible metallic electrode of proper size.

A very remarkable case of six years' duration referred to us by Dr. D. B. St. John Roosa, when the patient could smell nothing but fresh ground coffee and kerosene oil, was entirely cured by two applications of the faradic current.

CHAPTER XXVIII.

DISEASES OF THE EYE AND EAR.

For two reasons the diseases of the eye are not quite as amenable to electrization as corresponding or analogous diseases in some other parts of the body.

First. The anatomical position of the eye is such that the current cannot be directly localized in some of its parts; and secondly, the application of a very strong current is sometimes contra-indicated by the sensitiveness of the conjunctiva, and the possible injury that may be done to the brain.

For these reasons paresis and paralysis of the muscles of the eye—the conditions of the organ that are most frequently treated by electricity—cannot be as successfully subjected to electro-diagnosis or therapeutics as the same conditions of many other muscles, although therapeutic results in many instances of a decided character are obtained from electrization of the paretic or paralyzed muscles.

The principal diseases of the eye for which electricity has been employed with more or less success are:

Paralysis of the Muscles,	Ptosis,
Asthenopia,	Opacities of the Cornea,
Retinal Hyperæsthesia,	Photophobia,
Amaurosis and Amblyopia,	Granular Conjunctivitis,
Spasm of the Lid,	and Neuro-retinitis.

Electrization of the Eye.—The electric current affects the eye both directly and through reflex action from the fifth pair, and also through the sympathetic. As has been stated, the anatomical position of the eye within its bony cavity makes it impossible to reach all its parts as directly as could be desired; while the exceeding delicacy of its structure makes it at least very difficult to make the applications immediately to the conjunctiva.

The eye may be electrized in a general way, in asthenopia, for example, by pressing one large positive electrode over the closed eye, and the other at the occiput or by the side of the head above the cheek-bone; or one of the electrodes may be held in the hand. When it is desired to produce chemic changes in the eye this stable method of application may be used for some time. Placing the positive pole on the forehead or in the auriculo-maxillary fossa, the superior oblique may be excited with the negative pole on the upper and inner part of the orbit; the inferior oblique and rectus internus near the inner angle of the eye on the side of the nose; the rectus externus at the outer angle of the eye; the rectus superior at the upper part, and the rectus inferior at the lower part of the eyeball. Galvanization of the eye with interrupted currents to affect the muscles should usually be short, but stable or labile faradization with large electrodes may sometimes be made for a much longer time—three to ten minutes.

Paresis (exhaustion) or paralysis of the muscles of the eye may arise from cerebral lesions, or may be of a peripheral character. Locomotor ataxia is frequently preceded or accompanied by disorders of the muscles of the eye.

For the purpose of affecting the muscles of the eye the galvanic current is usually superior to the faradic. Galvanization of the sympathetic should also be tried in those cases that are supposed to be of cerebral origin. Short treatments, from one-quarter of a minute to one or two minutes, are preferable to longer applications. In these conditions protracted *séances* not unfrequently do injury.

Here, as elsewhere, the sensitiveness of the patient and the results in each case are perhaps the best guide. And yet it is always well to be cautious in the first application. In diseases of the eye, as of other parts of the body, we meet with exceptional cases that will bear and be benefited by very protracted applications of mild galvanic currents.

The unfortunate accident that happened to Duchenne—total destruction of the sight of a patient immediately after galvanization—did much for a time to retard the electro-therapeutics of the eye. The accident, however, has never been repeated, although the electro-therapeutists of the present day galvanize the eye and the brain with great freedom.

Localized faradization has been somewhat successful in the treatment of paralysis of the muscles of the eye in the hands of Meyer,* Soelberg Wells,† and Althaus.‡ Althaus has succeeded with the faradic current after failure with the galvanic. The current reverser electrode is very convenient for the treatment of paralysis of the muscles of the eye.

Prognosis in Paralysis of the Muscles of the Eye.—The prognosis of paralysis of the eye that depends on cerebral lesions is usually unfavorable. Cases that arise in the early stages of disease of the brain or spinal cord, as locomotor ataxia, and early syphilitic cases, offer good prognosis, though they are disposed to relapse.

Peripheral cases, when taken in the early stages, have a very favorable prognosis, but not so with cases that are long standing.

Benedikt, speaking of the prognosis in cases of paralysis of the eye, declares that of eight cases, from various causes, that were sent to him by

* Op. cit., p. 378. † "Diseases of the Eye," 1869, p. 568. ‡ Op. cit., p. 495.

Wecker, of Paris, in seven there was immediate improvement.* The same writer states that when the absolute excursive capacity of the pupil is little altered, but double vision is present in a great part of the visual field, the prognosis is unfavorable.

In some cases improvement follows early, after one or two sittings, or during the midst of the sitting; in other cases not until ten or fifteen.

The tendency with patients and physicians is to abandon treatment in paralysis of muscles of the eye without giving it a fair trial. They certainly demand as long treatment as analogous affections in other parts of the body.

Asthenopia.—Asthenopia may depend on an absolute correlative deficiency of energy in the muscle of accommodation; or of the internal recti. It is accompanied by hyperæsthesia of the retina and ciliary nerves.† Of these two forms, the accommodative and muscular, the accommodative is the more frequent. The marked effects in improving the tone of exhausted muscles in other parts of the body, produced by electrization, would lead us to suppose that asthenopia might be benefited by passing either the faradic or galvanic current through the eye.

In quite a number of cases of weakness of eye with hyperæsthesia, that have not been accurately recorded, we have obtained positive and rapid results. For those very numerous cases of eyes that ache severely if used even for a little time before breakfast, or at twilight, or in reading fine print, or doing fine needlework, or from exposure to glaring light; that perhaps are annoyed by muscæ volitantes and by neuralgic pains in or near the eye, and yet in which ophthalmoscopic examination reveals no lesion—for such cases mild labile faradization for five or ten minutes through the eye with the positive pole, either with a moistened sponge or the hand of the operator, while the negative is at the back of the neck or in the hand of the patient, is certainly a most agreeable and efficacious remedy. Stable galvanization is also useful in the same condition. Cases of this kind that are associated with general feebleness, with hysteria and dyspepsia, are sometimes much benefited by general faradization even when the eye receives no local treatment whatever. The tired, aching eye is both temporarily rested and relieved after each sitting, and permanently strengthened by continued treatment. In such cases electrization does for the eye what it does for the stomach or larynx, when they are in a condition of fatigue.

We believe that electro-therapeutics promises more for asthenopia, with hyperæsthesia of the retina, than for any other disease of the eye.

From the known effects of electrization on neuralgic and muscular

* Op. cit., p. 292.

† Stellwag, "Treatise on Diseases of the Eye," translated by Drs. Hackley and Roosa, p. 622.

weakness of other parts of the body, it would certainly appear that asthenopia, even in its severe phases, might also be successfully treated by the same agent. The subject is worthy of the earnest attention of ophthalmologists.

Amblyopia and Amaurosis.—Amblyopia is now understood to be a disorder of vision dependent on disturbance of the circulation, while amaurosis is to be regarded as a symptom of atrophy of the optic nerve.

For some of these conditions electrization may be tried with advantage.

A strong encouragement for a faithful trial of electricity in these cases is that various degrees of impairment of vision, from complete blindness through the lower grades, have been sometimes most successfully treated by physicians and charlatans with diverse methods of application. De Saussure cured a case of amaurosis by static electricity. Lesueur, Magendie, and Person successfully used faradization in the same cases.

What is now needed is a careful and persevering trial of galvanization and faradization in cases of amblyopia and amaurosis, after accurate ophthalmoscopic examination.

Spasm of the Lid (Blepharospasm).—For spasm of the levator palpebræ and orbicularis palpebrarum, faradization or galvanization is indicated for the same reason that it is indicated in torticollis, facial spasm, and spasm of the glottis.

The method of application is the same as that prescribed for asthenopia.

Prognosis.—Recent and mild cases recover rapidly. Long-standing cases are sometimes very obstinate, but even these are frequently relieved for a limited time after each sitting.

Opacities of the Cornea.—The electric currents have been employed with more or less success for opacities of the cornea for many years. Cases have been reported by Isiglio, Quadri, Willebrand, Türck, and Graefe. Recently this method has been but little employed.

The galvanic current would be more indicated than the faradic. External or internal applications may be used.

In a case of opacity of the cornea, resulting from herpes ophthalmicus, sent to us by Dr. Prout, there was a very decided clearing up under a protracted use of the negative pole of the galvanic current applied to the closed lid, and a part of the time directly to the conjunctiva, which had been rendered anæsthetic by the herpes. Alleman,* of New York, believes that the increase in nutrition aids to absorb the cicatricial tissue and reports favorable results.

Opacities of the Vitreous Humor—Keratitis.—Le Fort and Carnus report interesting and remarkable results in the treatment of opacities of

* L'Electrothérapie, Paris, September, 1891.

the vitreous humor by the galvanic current. The applications were made with one pole over the closed eyelid, and the other in the auriculo-maxillary fossa, to affect at the same time the nutrition of the eye through the sympathetic. In some of the cases the opacity was associated with or resulted from keratitis. Alleman has seen the blepharospasm and pain markedly relieved by one and a half milliamperes for five minutes.

Photophobia.—Photophobia is a symptom of so many different pathological conditions that the cases of cure or relief obtained in it by the electric currents are of comparatively little value. It very frequently depends on the diseases of the conjunctiva and cornea. Hewson reports the cure by galvanization of thirty-two cases of photophobia dependent on scrofulous inflammation of the cornea in children. From one to three applications were sufficient.

The positive pole was applied to the face and the negative to the supra-orbital foramen.

Ptosis.—This affection, which consists in paralysis of the elevator of the upper lid, is to be treated like spasm of the lid, but with a stronger current.

Granular Conjunctivitis.—In this condition the direct application of the galvanic current has been followed by some encouraging results and is worthy of further trial.

Neuro-retinitis.—On the theory that neuro-retinitis may depend on some morbid condition of the sympathetic, which in its turn may be connected with various cerebral affections,* it has been treated by galvanization of the sympathetic, and of the brain.

Indeed, from our experiments in galvanization of the sympathetic it would appear that in neuro-retinitis, and, indeed, in all affections where we wish to affect the vascular condition of the retina, galvanization of the sympathetic would very properly be indicated in connection with other remedies directed to the disease. The subject is certainly worthy of investigation.

Strabismus.—In strabismus, dependent on merely transitory causes, faradization or galvanization may be of service; but the results yet reported are not of great importance.

That temporary relief of strabismus may be derived from faradization we demonstrated in several instances. The method of application is the same as that for paralysis of the muscles.

Cataract.—The literature relating to the use of galvanism in the treatment of cataract is very considerable, but, at the same time, both the opinions and statements are very conflicting. Crussel, of St. Petersburg, claimed to have had successes. His method was to introduce into the lens a needle connected with the negative pole, while the positive was

* Benedikt, op. cit., pp. 252, 253, 254.

applied to the tongue. In this way the cataract was subjected to the three factors of mechanical disintegration by the needle, to the chemic influence of the negative pole, and "probably, also, to the macerating action of the aqueous humor penetrating the lens through the puncture made in the capsule by the needle." Bergmann, Newmann, Mildner, Benedikt, Strauch, and others, on the contrary, claim that the results are not sufficiently favorable to counterbalance the dangerous inflammation that is liable to follow.* Rosenthal used external applications, and claimed to have cured two out of three patients whom he thus treated. Two cases of cures have been reported by Neftel. The cases were subsequently examined by Drs. Agnew and Knapp, who failed to find evidence of any improvement that could be attributed to electricity.

Among other diseases of the eye in which electricity may be tried experimentally, with the hope of greater or less success, are anæsthesia optica and nystagmus.

Diseases of the Ear.—The diseases of the ear are less amenable to treatment by electricity than analogous diseases in most other parts of the body. By its anatomical position the internal ear is even more inaccessible than the eye; and even the parts which can be brought more directly under the influence of electrization, as the middle ear, the membrana tympani, and external auditory canal, can bear only feeble currents. Hence it is that there is no branch of electro-therapeutics where there has been such general disappointment both among aurists and electro-therapeutists as in diseases of the ear.

The morbid conditions of the ear for which electrization has been found of some service are subacute and chronic inflammation of the drum and middle ear, nervous deafness, and tinnitus aurium.

Experiments on the ear were made quite early in the history of electro-therapeutics.

Brenner† gives the following bibliography of this department in the early part of the present century:

AUGUSTIN: "Versuch einer Geschichte der galvanischen Elektricität und ihrer medicinischen Anwendung," Berlin, 1801 (this work contains a quantitative distinction in the working of both poles on the nerves of hearing); also, "Von Galvanismus und dessen Anwendung," 1801, by the same author.—MERZDORFF: "Behandlung des Ohrensausens durch den Galvanischen Strom," bei GRAPENGIESSER, 1801, pp. 131 and 132.—FLIES: "Galvano-therapeutische Versuche," Ebendas., 1801, pp. 241, 252.—Stellwag: "Ueber Galvanismus," Hamburg, 1802 (this work contains cures of deafness).—STRUWE: "System der Medicinischen Elektricität mit Rücksicht auf den Galvanismus," 1802.—

* For the literature of the subject consult Canstatt's Jahresbericht for 1841–45 also Schmidt's Jahrbücher for 1841–42. quoted from Evetzky's article "On the Nature of Cataract," etc., New York Medical Journal, July, 1880, to which we are indebted.

† "Untersuchungen und Beobachtungen auf dem Gebiete der Electrotherapie," I Band, I Abth., 1868, p. 40.

WOLKE: "Nachricht von den zu Fever durch die Galvani-Voltaische Gehörgebekunst beglückten Taubstummen," etc., Osnabrück, 1802.—MARTENS' "Therapeutische Anwendung des Galvanismus," 1803.

It was natural that attempts to cure diseases of the ear should be made thus early in the history of electro-therapeutics, because at that time there was scarcely any other method of treatment.

There are two general methods of electrizing the ear—internal and external.

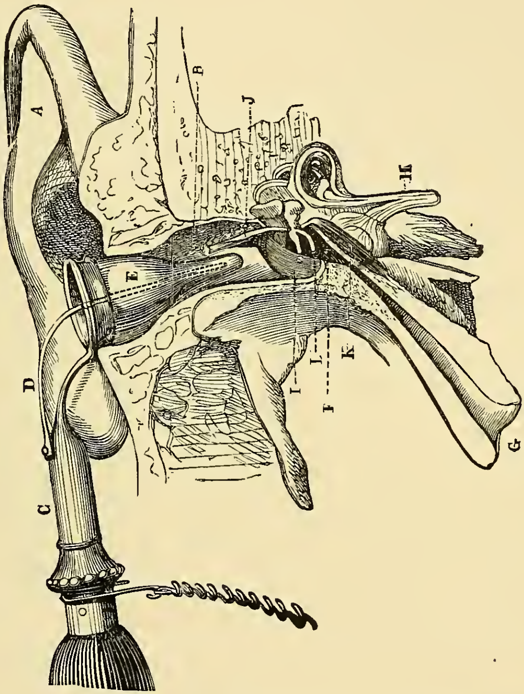


FIG. 171.—Internal Method of Electrization of the Ear (Duchenne).

A, Auricle; *B*, external auditory canal; *C*, handle of electrode; *D*, flexible wire; *E*, rubber speculum; *F*, ossicula in middle ear; *G*, mouth of tube; *H*, auditory nerve in inner ear; *I*, inferior half membrana tympani; *J*, external muscle of hammer; *K*, internal muscle of hammer.

The flexible wire can be pressed in toward the drum and then allowed to spring back. The external auditory canal is very sensitive, and only mild currents, or currents quickly interrupted, will be borne. The other electrode may be placed in the hand of the opposite side, or at the mouth of the Eustachian tube, by means of a metallic-pointed insulated catheter. It is an advantage before making the application to partly fill, or at least to moisten, the ear with warm salt water, since thereby the conduction is much increased. The water should be warm, because cold water is not well borne in the ear.

External Method.—The best external method of electrizing the ear is to press the electrode firmly on the tragus, the other electrode being held, as before, in the hand of the opposite side. The ear should be filled with warm salt water, although this is not necessary.

We have used this method for several years with both the faradic and galvanic currents, and prefer it for all cases except when it is desired to act directly on the inflamed surfaces of the drum, or middle ear. It is far less painful and more satisfactory than the internal method. It may be used on the most sensitive children, who would rebel against the internal method, however skilfully performed.

The sitting should not usually be more than five or ten minutes, and in some cases much shorter applications should be used, especially when the galvanic current is used.

The electro-physiology of the ear has already been described in the section on Electro-Physiology.

Electro-Diagnosis.—The electro-diagnosis of diseases of the ear has been specially studied by Brenner.

The leading idea of this observer * is that the reaction of the auditory nerve to the galvanic current is variously changed by pathologic conditions.

The normal formula has already been given. (See Electro-Physiology.)

The difficulties in the practical application of this method of electro-diagnosis are very great. The normal formula can be obtained only in a certain proportion of cases, and then oftentimes by painful currents. Even when we obtain apparent deviations from the normal formula, we are not always sure just what such deviation indicates, either in special pathology or in therapeutics.

Changes in the Reaction of the Auditory Nerve in Pathologic Cases.—In pathologic cases the normal formula may undergo various changes.

These changes in the reactions that appear in diseases of the ear may be embraced under the following heads:†

1. Hyperæsthesia of the nerve, so that it reacts to a milder current than normal, or reacts longer or more powerfully. This may be either simple or complicated with qualitative change in the formula, or with

* "Zur Elektrophysiologie und Elektropathologie des Nervus Acusticus," Petersburger med. Zeitschr., Bd. 4, p. 286, 1863. Also, "Weitere Mittheilungen zur Elektro-otratrik," Petersburger med. Zeitschr., Bd. 5, p. 35, 1863. And more recently in his published work, "Untersuchungen und Beobachtungen auf dem Gebiete der Elektrotherapie," Leipzig, 1868 and 1869.

† Brenner: Op. cit., Band i., p. 181 et seq.

paradoxical formula in the ear not experimented on, or with morbid subjective sensations of hearing.

2. Change in the formula of reaction without hyperæsthesia. These changes are either in inversion of the normal formula, or deviations of various kinds.

3. Torpor of the nerve (anæsthesia), so that it does not react, or only to a stronger current than normal.

General Therapeutic Results of Electric Treatment of Diseases of the Ear.—In the United States, cures of deafness, without regard to the pathology on which the symptom of deafness depends, have occasionally been accomplished by uneducated empirics, who have treated all forms of disease of the ear, from inspissated cerumen to disease of the auditory nerve, by some unscientific and uniform method of faradization.

Duchenne reports one case by faradization of hysterical deafness of many months' standing; one caused by quinine; one consecutive to an eruptive fever; one following measles; one of twenty years' standing. Several cases of nervous deaf-muteism were also improved.

The conclusions to which he arrived are as follows: *

1. "That nervous hysterical deafness is generally cured by electric excitation of the chorda tympani and movements of the chain of little bones."

2. "That cases of nervous deafness consecutive to eruptive and continued fevers have been cured by the same treatment, even though they have been of long standing, and, from the fact of their resistance to ordinary remedies, have appeared to be incurable."

3. "That probably the therapeutical action of the process of faradization is chiefly due to the undulations of the labyrinthine liquid produced by the movements of the chain of little bones, and consequently of the fenestra ovali."

4. "That electric exploration of the ear furnishes no pathognomonic sign which permits the prognosis of incurability of the deafness."

Subacute and Chronic Inflammation of the Middle Ear.—As far as we can judge from our own observations, old cases of chronic inflammation of the middle ear, where the hearing power is so much impaired that a watch can be heard only on pressure, offer an unfavorable prognosis.

The best results are obtained in those cases that are just passing from the subacute to the chronic stage. We are inclined to the belief that these results, when they do occur, are brought about by the mechanical action of the faradic current on the adhesions within the middle ear. In some even long-standing cases of chronic inflammation of the middle ear temporary improvement of hearing immediately follows faradization or galvanization.

* "Treatise on Diseases of the Ear," translated and edited by Dr. D. B. St. John Roosa, second American edition, 1869, pp. 1013, 1030.

Tinnitus Aurium.—The very frequent and very distressing symptom, tinnitus aurium, and which accompanies so many of the morbid processes in the auditory apparatus, is not relieved by electric treatment as uniformly as *a priori* reasons would lead us to expect. The capriciousness and uncertainty of the results in such cases are partly to be explained by the fact that tinnitus aurium is a symptom of such diverse and sometimes undiscoverable pathologic conditions. Local galvanization by the external method, or galvanization of the sympathetic, sometimes avails for the temporary relief of this affection, and in some cases a more or less permanent cure is obtained.

Galvanization of the cervical sympathetic affects the ear just as it affects the retina, through modification of the circulation in the brain. Dr. Rumbold, of St. Louis, reports two cases of tinnitus aurium in which local galvanization was of great service.*

With reference to the therapeutic value of the galvanic current, especially in the treatment of diseases of the ear, Brenner † and Hagen ‡ substantially agree to the following propositions:

1. The galvanic current is indicated not only for those cases where no morbid changes can be diagnosticated, but also in all cases, however complicated, in which the abnormal reaction to the current shows that the nerve participates in the disease.

2. The galvanic treatment may aid in the absorption of morbid deposits.

From our survey of the literature of the subject, and from our own comparative observations, we are justified in these two conclusions:

First. The galvanic current is on the whole of greater service, and is of greater promise in the electro-therapeutics of the ear than the faradic.

Second. The results obtained in the electric examinations are not uniform or always reliable guides to the special method of treatment that it is best to adopt.

Reasoning *a priori*, it would be inferred that the reaction of hyperæsthesia would call for treatment by the anode, and the reaction of torpor (anæsthesia) for treatment by the cathode; but experience shows that there is no uniformity to this law.

Moos § found that the cathode at one time exercised a temporarily beneficial influence on the subjective symptoms, which usually disappeared only under the anode.

Erb ‖ also, in case of "simple hyperæsthesia of the right auditory nerve," with "inversion of the normal formula," found that the tinnitus

* Archives of Electrology and Neurology, May, 1874.

† Op. cit., Band i., p. 262.

‡ "Praktische Beiträge zur Ohrenheilkunde," Leipzig, 1866, p. 29.

§ Archives Ophthal. and Otol., vol. 1., No. 2, p, 488.

‖ Archives Ophthal. and Otol., vol. i., No. 1, p. 28.

was quieted by the closing of the cathode (KaS) and not by the closing of the anode, as would have been expected.

Still further, it is not demonstrated that in many of the cases of hyperæsthesia that were successfully treated by the anode, or of torpor (anæsthesia) that were successfully treated by the cathode, the results might have been equally or more successful if the poles had been reversed. The conclusion is, therefore, that while the general law laid down, that the positive pole is on the whole the more calming and the negative the more irritating, applies to the auditory nerve as to other parts of the body, yet it is always liable to many real or apparent exceptions, and in the present state of our knowledge the rule can never be made an absolute or uniform guide in the electro-therapeutics of the ear.

Brenner * details eleven cases of diseases of the ear treated by the galvanic current.

In one case of thickening of the drum, the current caused absorption.

In one case of hyperæsthesia, with tinnitus aurium and anatomical changes in the middle ear, the tinnitus was rapidly cured.

In one case of hyperæsthesia, after the use of quinine there was recovery.

In one case of hyperæsthesia, with tinnitus aurium and catarrh of the middle ear, the tinnitus was cured.

In one case of obstinate subjective symptoms of various kinds there was improvement under great difficulties of application.

In one case of noises in the head and ears, of ten years' standing, with important anatomical changes in the ear, there was improvement.

Of deafness, two cases were improved, one was much improved, and one was cured. The case which recovered was one of facial paralysis, with anomalous reaction of the auditory nerves.

In all the cases there were anatomical changes.

In some cases the treatment was quite persistent.

Hysterical Deafness.—When deafness depends on simple hysteria the results of electric treatment may be very brilliant.

Dr. Moos, of Heidelberg, has published a case of recovery from hysterical deafness under the influence of the galvanic current, which is the most remarkable of any which have been scientifically reported.

Deafness following Cerebro-Spinal Fever.—Our own experiments in the electric treatment of deafness, following cerebro-spinal fever, have been entirely unsatisfactory.

Moos† relates a case of cerebro-spinal meningitis that was followed by complete deafness that gradually improved so that he could hear one or two feet. The patient was troubled with tinnitus aurium and also with

* Op. cit., Band i., 2 Abth., p. 233 et seq. Brenner also mentions the fact that he failed in seventeen cases of tinnitus. Loc. cit., p. 235.

† Archives of Ophthalmology and Otology, vol. ii., No. 1, p. 332.

headache and vertigo. With the right ear he heard nothing; with the left ear could hear the voice two feet. Temporarily the anode produced a diminution of the subjective noises. After twenty-two sittings the hearing power was raised to eighteen paces; the noises and giddiness were much diminished.

Chronic Suppuration of the Middle Ear.—We have experimented somewhat in the treatment of chronic suppuration of the middle ear by the local use of the galvanic current. The experiments were made both in private practice and at the Brooklyn Eye and Ear Hospital in connection with Drs. Matthewson, Newton, and Prout. The theory on which the experiments were based was that ulcerous conditions in the ear might be treated electrically just like similar conditions in other parts. Ulcers on the mucous membrane do not yield as readily to electric treatment as ulcers on the surface of the body, and do not bear electricity as well; they are, however, somewhat susceptible of electric treatment, as is shown by experiments in chronic urethritis and granular lids.

The method of treatment adopted in these experiments was to insert an electrode with a long narrow extremity, covered with a little cotton, into the auditory canal, through a rubber speculum, the canal being filled with tepid water. The electrode is usually connected with the negative pole of the galvanic current, though sometimes with the positive pole. The circuit is completed by the hand of the patient holding a sponge electrode or resting on a stationary electrode. Only very weak currents and very short applications are borne, and it is almost indispensable to have some kind of rheostat, so that the current may be gradually shut on or off.

Under this treatment the character of the discharge changes, and in some cases the recovery was certainly more rapid and satisfactory than it would have been without it.*

* Vide Dr. Roosa, "Treatise on Diseases of the Ear."

CHAPTER XXIX.

MIDWIFERY.

The use of electricity in midwifery was first recommended by Bertholon and Herder (1803). Kilian afterwards used "galvanic obstetric forceps," made of two metals.* Faradic currents were first used for bringing on labor-pains by Höniger, Zyly, and Jacoby, of Neustadt, in 1844. Since that time the same agent has been used for this purpose by authorities too numerous to mention and by practitioners everywhere.

The indication for the use of the current in midwifery is declared to be an adynamic condition of the uterus, when other conditions are favorable for or necessitate immediate delivery. Dempsey records a case where, after ergot in large doses had failed, faradization for forty minutes produced uterine contractions that resulted in the delivery of the child.

Frank reports a case of miscarriage from a fall, in which faradization produced contractions of the uterus, and stopped the very profuse hemorrhage. Mackenzie succeeded in stopping the hemorrhage in two cases of placenta prævia. In one case the current was applied for six, and in the other for three hours.†

These observers claim that electricity acts more quickly, more uniformly, and with less injurious effects than ergot.‡

Both M. de Saint Germain and Tripier are highly in favor of faradization in the last stages of delivery. When the labor has fairly begun, the pains coming on at intervals of about a quarter of an hour, Tripier faradizes the lumbar region.

Uterine contractions soon follow and occur more frequently, while the dilatation of the neck takes place rapidly. In cases of confinement M. Tripier always faradizes the lumbar region by means of two electrodes, and sometimes he applies one pole directly to the uterus. According to his account the placenta is expelled immediately after the fœtus, and although it was evident that the child felt the current, not the slightest injury has ever been inflicted.§ During the last few years there has been a revival of interest in the use of faradization in midwifery. Quite a number of observers in different countries have reported good results.

* Meyer: Op. cit., p. 452.

† Journal de Médecine.

‡ Quoted by Meyer: Op. cit., pp. 452.

§ Simpson and Scanzoni, on the other hand, deny the utility of electricity in midwifery.

Dr. A. Murray, of this city, informs us that he has treated eighty-two cases of inertia uteri, in second stage of labor, by external faradization, and always with good results. He states that it acts much more speedily than ergot. His method is to place one pole on the sacrum and the other over the abdomen. The applications are continued from eight to ten minutes.

Post-Partum Hemorrhage.—Faradization has also been used with good effect in post-partum hemorrhage. The old method of introducing one electrode of an induction apparatus into the uterus and applying the other over the abdomen is in many cases efficient and has undoubtedly saved many lives, by the promptness with which it induced uterine contractions. The efficiency and promptness of this method, however, are not nearly so great as the bipolar method, when both poles are introduced into the uterus and the induced current of quantity employed. In the treatment of post-partum hemorrhage it is of the greatest importance that the wide difference between the action of the currents of quantity and tension on the uterine tissues be thoroughly appreciated. One who is accustomed only to external applications would very naturally, if suddenly called upon to treat a case of post-partum hemorrhage, use the current of tension, which ordinary experience has shown to be so much stronger than the other. In doing this, however, he would be likely, if there existed a marked adynamic condition of the uterus, to fail utterly in inducing any adequate muscular contractions, and a fatal hemorrhage ensue with a remedy at hand capable of successfully combating it. In all such treatment it is hardly necessary to say that one should exercise the most careful antiseptic precautions.

Diseases of the Mammary Gland—Deficient Lacteal Secretion.—Secretion of milk may be increased by electrization. Two methods of faradization have been proposed, one by means of moist electrodes on the gland, the other by dry electrodes, with a view to excite the secretion of the gland by reflex action.

Successful cases have been reported by Aubert and Becquerel.* Aubert cured one of his cases by dry, the other by moist electrodes. In the first case the patient had no milk three weeks after parturition. After a delay of seven months the treatment was applied. The third application brought on a milk-fever; after the fifth milk appeared. In the other case the mother was attacked by pneumonia eleven and one-half months after confinement. As a consequence the lacteal secretion ceased. Four faradizations with moist electrodes filled the breasts.

In Becquerel's case recovery was obtained by three applications. Similar results have been obtained by other observers.

Dr. Skinner, of Liverpool (quoted by Althaus), reports a case of a lady

* Quoted by Meyer: Op. cit., pp. 451 and 452.

who, while nursing her fifth child, suffered complete suppression of the lacteal secretion, which the doctor attributed to the tincture of iron she was taking. He applied the current (probably the faradic, which, on account of its greater mechanical effects, would be more indicated in such cases) to the left breast. The patient felt a rush of milk to the breast, and in a few hours a full supply appeared.

The right breast had not been used for some time, on account of a previous abscess. As a new experiment, the doctor made two applications of five minutes each to this breast, and brought on as much milk as in the other.

Dr. A. Murray informs us that he has tried faradization as a galactagogue in thirty-seven cases. He found it efficacious in about two-thirds of the cases.

Sore Nipples.—Sore nipples, like ulcers and fistulæ in general, may be treated electrically by either current, but the galvanic is preferable.

Different forms of galvanic nipple-shields have been devised. These act like the electric disks and other body batteries.

Extra-Uterine Pregnancy.—So far as known the first case of ectopic

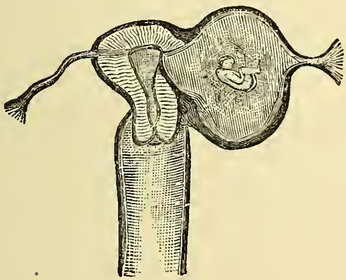


FIG. 172.

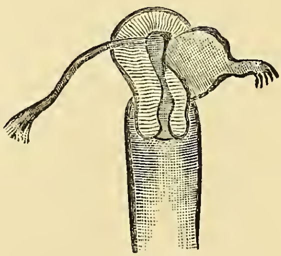


FIG. 173.

gestation treated by electricity in this country was by Allen, of Philadelphia, in 1869; but as early as 1853 Bachetti, in Italy, and in 1866 Hicks, in England, each treated a case. It was not, however, until 1878 that the treatment began to receive any sort of recognition, and it was due to the following remarkable case which we treated for Dr. McBurney, and which will be found more fully reported by him in the New York *Medical Journal*, Vol. XXII. No 3.

Dr. McBurney first detected this condition in a young woman aged twenty-two, and called in Drs. T. G. Thomas and T. Addis Emmet, who not only confirmed the diagnosis but one of tubo-interstitial pregnancy at the third month. An operation was advised, but before attempting this Dr. Thomas suggested the use of electricity. Our opinion being asked whether it were possible to destroy the life of the fœtus by the electric current, we replied that it could undoubtedly be done, but the important question was whether it could be accomplished without injury to the mother, It was decided to make the trial, which proved entirely successful by the expulsion of the fœtus and placenta through the uterus.

The impression made upon the minds of the physicians interested as to the approximate condition of affairs in this case both before and after the expulsion of the fœtus is best represented by sketches made by Dr. Thomas (Figs. 172, 173). The publication of this case excited great interest both here and abroad, which was intensified by the additional cases which followed rapidly upon the first.

The second case upon which we operated was in the practice of Dr. C. E. Billington, the accuracy of whose diagnosis was again confirmed by Dr. Thomas. The result in this case was entirely successful.

The third case we treated for Dr. Bache Emmet, who had in consultation both Dr. T. Addis Emmet and Dr. T. G. Thomas. Dr. Emmet's account of the case, with its favorable termination, may be found in the New York *Medical Journal.*

In the fourth case we operated for Dr. Everett Herrick, the diagnosis being doubly confirmed by Drs. Thomas and Emmet. In this case again the fœtus was effectually destroyed, followed by the prompt recovery of the mother.

The fifth case which we saw with Dr. N. S. Westcott, was of a most interesting and unusual character, from the fact that with a normal uterine pregnancy was associated what we have every reason to believe was a tubal or extra-uterine pregnancy. Dr. Westcott had previously called Dr. Thomas in consultation, and it was at his suggestion that electricity was used. The patient, a lady aged about thirty, last menstruated August 6th, 1882. Subsequently she complained of more or less discomfort and pain, with tenderness in the region of both ovaries, but especially marked on the left side. On September 18th, an internal examination was made, and by conjoined manipulation a small tumor was discovered, about the size of a pullet's egg. It was situated some two inches to the left of the median line, nearly on a level with the brim of the pelvis, and could be moved from Douglas' cul-de-sac toward the margin of the ribs. The tumor gradually increased until it was larger than a billiard-ball. There seemed to be no reasonable doubt as to its character, and on October 24th the treatment by electricity was attempted.

The constant current was used, with one pole introduced to the mass through the vagina, and the other over the tumor externally and with rapid interruptions.

This operation was repeated on October 25th, 28th, and 30th, causing the tumor not only to perceptibly decrease in size, but to change its seat by an inch or so as well. Since the last treatment it has gradually grown smaller until at the present date it can barely be detected. At the same time there is now developing in the uterus a six months' fœtus.

The sixth case occurred in the person of a young unmarried woman, residing outside the city limits, and by special request, and for sufficient reasons, the name of the attending physician will not be mentioned. From him the following history was obtained: Two weeks previously he first saw the case professionally, and found that she was suffering much pain in the right side, together with irregular discharges of blood. The patient had confessed to the possibility of pregnancy, and examination elicited many of the objective and subjective signs of this condition. Nausea occurred every morning, and changes had taken place in the areola. Digital examination revealed the fact that the os uteri was little, if any, changed from its normal condition. By pressure over the right side it was possible to feel a certain hardness not present on the other side, but by conjoined manipulation, with one finger in the vagina, a distinct rounded mass could be felt.

Examination per rectum revealed its presence even more distinctly. If pregnancy existed—and of this there seemed to be no reasonable doubt—it had advanced nearly to the fourth month, and as the tumor was large, much larger than in the case just related, there was evidently no time to lose. We had brought with us a suitable apparatus, and immediately operated by introducing one pole to the rectum and placing the other externally. On account of the great distention of the Fallopian tube, and the danger of rupture, we felt the necessity of exercising the utmost care. The current would be quickly increased without interruption and allowed for a moment to pass in a continuous stream and as quickly decreased The treatment was concluded by a second application on the following day. Visiting the patient some two weeks subsequently, we found that the tumor had decreased in size at least one-half, and at this time, after the lapse of several months, it may be said, so far as any external evidence of it is concerned, to have entirely disappeared.

Another case is as follows: On December 14th, 1882, we were informed by Dr. H. Marion Sims that Mrs. A——, a patient of his, was suffering from extra-uterine pregnancy, and was by him requested to undertake the destruction of the fœtus by electricity.

Although married a number of years, she had never before been pregnant. Dr. Sims, on first discovering the possibilities of this condition, called in consultation Dr. T. Addis Emmet, who positively confirmed the diagnosis. The pregnancy had advanced to the third month, and the tumor, which was about the size of a child's fist, was movable and could be distinctly felt both from without and within.

The size of the enlargement was such that the operation was urged immediately. For fear that the cyst might be in danger of rupture through uncontrollable movements of the patient, Dr. Emmet advised the administration of an anæsthetic.

Ether having been given by Dr. M. H. Nash, the uterine electrode was placed in position and the current passed through the fœtal mass.

Although it was probable that the destruction of the fœtal life had been effected at the first *séance* the operation was repeated on the 18th, 24th, and 27th of December for the purpose, first, of absolute certainty, and second, to accelerate the absorptive process. The contour and seat of the tumor were not only changed after the first application but rapidly decreased in size. The patient experienced no unpleasant effects, and within a short time was able to start for Europe.

In addition to these we have operated upon many other cases and with uniformly good results except in one case. This case was in the practice of Dr. Janvrin, but the death of the patient was admittedly not because of but in spite of the treatment. Hemorrhage began evidently before the electricity was used.

In the treatment of extra-uterine pregnancy it is an important point to be decided as to the best form of electricity to be used. Not only has the galvanic current and electro-magnetism been successfully employed, but it is said that the common magneto-electric battery has also proved sufficient; but from both a physical and physiologic point of view, and as well through the teachings of experience, we cannot, for our part, doubt that the galvanic current is preferable to the other forms. It is more certain in its effects. Four important effects attend the passage of the electric current through the living body, and all these undoubtedly enter as factors, either in destroying the life of the fœtus or in the subsequent process of absorption.

These effects may be designated as mechanic, physical, chemic, and physiologic.

The mechanic effects of the interrupted galvanic current are equal to those of the faradic current, while the physical effects, manifested by heat, and the modification of endosmose and exosmose are in the main the results of galvanic action.

By the passage of the galvanic current, the endosmotic phenomena may be both stimulated and reversed. The faradic current from the secondary coil produces no such effect. The current from the inner coil produces these effects but in a much less degree. Chemic or electrolytic effects, again, are almost wholly the result of galvanic action, and it should be remembered that the electrolysis of organic substances starts a process that continues long after the current ceases to flow. The physiologic effects of electricity are those which take place by virtue of the vital properties of the body and, unlike the other effects, are only observed in living substances. Physiologic effects are manifested on the circulation, on secretion and excretion, but only as absorption is effected does it interest us here, and it is quite evident that the absorptive powers of the secondary current are quite limited.

In any case of tubal pregnancy, and especially in those advanced conditions where the tube is greatly distended, and there is danger of spontaneous rupture, the possibility of hastening this catastrophe in the attempt to destroy the life of the fœtus should never be lost sight of. The tubes themselves are but slightly supplied with muscular fibre, and the danger would more especially arise from the powerful compression that is liable to be exerted by the abdominal muscles, and the effort should be so to diffuse the current proceeding from the external pole as to produce the least mechanic effect possible. In regard to the diagnosis of extra-uterine pregnancy, it must be confessed that it is not always an easy matter, and in the cases just related the question may arise as to its accuracy. The eminence of the gentlemen associated in the cases should perhaps be a sufficiently strong argument for the correctness of the diagnosis, but conclusive evidence lies also in the effects of the treatment itself. The results of the electrolysis are well known, but in no other form of tumor, cystic or otherwise, is it possible for the galvanic current, used as described, to produce similarly prompt and effective results. In regard to the effects of electricity on normal pregnancy, suggested by the case of double pregnancy that we have related, a word may be said. It is a mistake to suppose that abortions are readily produced by electricity. Without the electrode is introduced directly into the uterus, which would of course be sufficient without the passage of any current, the strongest treatment that it is prudent to give may prove insufficient. Of this we have had evidence in several justifiable attempts to bring on a miscarriage. In the case just alluded to the current was strong, applied by shocks, and in close proximity to the uterus, affecting it not only reflexly, but in some measure directly, yet the normal pregnancy was in no ways disturbed; and, so far as concerns general applications for the production of constitutional tonic effects, we have in many instances administered them with impunity through the whole course of gestation, and with the most happy results. The question may be asked, What becomes of the fœtal mass, after its destruction by the electricity? The probability is that it first becomes encysted and then gradually absorbed. At all events, in all of the foregoing cases, the enlargement entirely disappeared within a comparatively short time, and was not the cause of the slightest discomfort.

Brothers * has collected some very interesting and suggestive statistics upon this subject. Out of seventy-eight cases where electricity had been used without puncture, there was but one death, and in this case there were symptoms of hemorrhage previous to the resort to electricity. Notwithstanding the eminent success that has attended this simple method of electric treatment, it has seemed to fall into comparative neglect, which Brothers attributes to the "epidemic of laparotomy fever which, originating in Europe, has spread over our continent." Unprejudiced opinion

* American Journal of Obstetrics, May, 1888, and vol. xxiii., p. 113: "Present Position of the Electrical Treatment in Ectopic Gestation." Transactions of American Electro-Therapeutic Association, 1893.

is, however, undoubtedly in its favor, and it is a suggestive fact that those who are most pronounced in its denunciation are those who have the least experience in its use, while Thomas and Mundie,* Lusk,† Parvin,‡ Playfair,§ and many others whose opinions are based upon experience believe in it and still employ the method under judicious restrictions wherever it is properly indicated.

* "Diseases of Women," Philadelphia, 1891.

† "The Science and Art of Midwifery," New York, 1892.

‡ "The Science and Art of Obstetrics," Philadelphia, 1890.

§ "A Treatise on the Science and Practice of Midwifery," London, 1889.

CHAPTER XXX.

DISEASES OF THE HEART AND LUNGS—ARTIFICIAL RESPIRATION BY ELECTRIZATION.

Palpitation of the Heart; Tachycardia, Brachycardia.—That galvanization of the sympathetic and general electrization have a positively accelerating or sedative effect on the action of the heart, we have demonstrated by a large number of experiments. This effect is produced by the action of the current on the sympathetic or the pneumogastric in the neck, or in general electrization it may also result, secondarily, from the influence that the system at large receives from the application.

Cases of functional disturbance of the heart, associated with dyspepsia and hysteria and anæmia, we have found to yield to general faradization in a large variety of instances, even when no special attention was directed to the sympathetic or the pneumogastric.

Fliess experimented with the galvanic current in twenty-four cases, nineteen of which were functional, and five of an organic character.

All the cases were more or less relieved, even those dependent on structural lesion, while the majority of the functional cases were permanently cured.

His method of treatment was the daily application to the pneumogastric in the neck of mild, descending, galvanic currents, for one or two minutes. Temporary abatement of the symptoms followed each application. Brachycardia, or abnormal slowness of the pulse beat, we have known to be very materially benefited by the stimulating action of both currents.

The treatment of functional palpitation of the heart is certainly worthy of more attention than it has thus far received from electro-therapeutists.

Angina Pectoris.—The treatment of angina pectoris has ever been unsatisfactory. The cases that have fallen under our observation were mostly of a chronic character, and turned to electro-therapeutics as a last resort. We have seen the symptoms occasionally palliated, but very seldom any permanently good result.

Diseases of the Lungs.—For diseases of the lungs electrization has accomplished less than in any other department. The recognized gravity of phthisis, together with the *a priori* improbability that it could be directly cured by any known methods of using electricity—these two causes have deterred electro-therapeutists from making even experimental applications to diseased lungs. One author—Bastings,* of Brussels—however, has reported most astounding results from faradization of the muscles of the chest. If we accept in good faith the statements of this author, even the second stages of phthisis may be cured by this method, which seems to affect the lungs not directly, but indirectly, through the muscular development which it causes, and the greater amount of oxygen which it enables the lungs to breathe.

The amazing statements which the author advances concerning the cure of consumption are entitled to more consideration than they would otherwise receive, from the fact that the fundamental idea on which his treatment is based, namely, that faradization of the muscles—electro-muscular gymnastics—markedly increases their size and strength, and also improves the general nutrition, is eminently sound and thoroughly demonstrable, as we have shown during all our investigations in electro-therapeutics.

Vaust † has experimented with the method of Bastings—electro-muscular gymnastics—in growing children, who were not affected with any special diathesis, but who "presented the appearance of debility, languor, and lack of force so frequently found among the poorer classes."

The results were "wonderful." Not only were the muscles of the chest greatly increased in size after a number of applications, but their "breathing was deeper, their appetites better, and they were more cheerful and lively."

After six months' treatment the increase was still more marked in some of the cases. According to our experience, the growth of the muscles under faradization is at first quite rapid, but subsequently much slower, and in a few months becomes stationary.

Bastings has used these electro-muscular gymnastics in consumption, not with a view to directly affect the tuberculous deposit at all, but, by strengthening the muscles of the chest, so to improve the respiratory power that more air can be inspired, and so benefit result to the healthy portion of the lung, and indirectly, through better oxygenation of the blood, to a certain extent on the diseased portion and on the whole system.

The method and principles of treatment in all his cases were substantially similar—electro-muscular gymnastics: about half a minute was given to each muscle, and about five minutes to each sitting. Prolonged treatment was found to be injurious.

The general statements of the author were confirmed by Dr. Bougard,‡ who affirms that the patients remain cured for one, two, or three years.

* "Die Lungenschwindsucht und ihre Heilung durch Electricität," translated from the French by Dr. Silbermann. Erlangen, 1866.

† Medicinisches Journal, vol. 38, Juni 1864, p. 599. "Sitzung der Gesellschaft für Medicin und Naturwissenschaften zu Brüssel, vom. 2. Mai 1864." This paper is presented in the work of Bastings, above quoted, p. 119 et seq.

‡ Op. cit., p. 147. Loc. cit., p. 142 et seq.

Dr. Crocq also speaks favorably of the method of Bastings, although in the treatment under his own direction of the very severe cases of consumption in the St. John Hospital he obtained no positive results.

Although modern experience has failed to confirm these experiences of Bastings and others, yet the beneficial effects of muscular exercise in consumption have long been conceded, and it is within our experience that persistent and judicious applications of electricity, both general and local, sometimes give comfort and strength, and as an adjuvant to other methods has a useful place in the treatment of consumptives.

Artificial Respiration by Electrization.—The process of exciting artificial respiration by faradization * is as follows:

1. Let an assistant put the head, shoulders, and arms of the patient in a fixed position, while another stands ready to assist the expiratory movements by pressure.

2. Graduate the current to a strength sufficient to produce vigorous contractions of the muscles of the ball of the thumb, and then press the sponge electrodes (which should be of large size and well moistened) firmly over the phrenic nerves at the outer borders of the sterno-cleido-mastoid muscles and at the lower end of the scaleni muscles.

3. Interrupt the current (either by removing one of the electrodes or by an interrupter) about three times a minute, while the assistant presses firmly on the abdomen, pausing occasionally to observe the effect.

4. If after a number of interruptions no inspiratory movements appear, increase the strength of the current.

In some cases it is sufficient to put one electrode over the phrenic nerve and the other in the seventh intercostal space.

Large electrodes are used so as to affect the other muscles which have a share in inspiration (scalenus-anticus and sterno-cleido-mastoid) simultaneously with the phrenic nerve. The object of holding the arms and shoulders in a fixed position is to prevent the interference which may arise from the contractions of the muscles of the arms, and at the same time to obtain the co-operation of the serratus and pectoral muscles.

Professor Ziemssen, who first proposed this method of producing artificial respiration, advises the trial of the galvanic current in those cases where the irritability is lost to the faradic. The same writer presents a number of successful results in cases of poisoning by carbonic acid gas with this method of treatment from his own and other experience.†

In opium poisoning artificial respiration by faradization may be tried either alone or in connection with other methods. Dr. Iram has reported a case of opium poisoning, which recovered on the application of one pole

* The faradic current is usually employed for this purpose, although the interrupted galvanic current might answer the purpose.

† "Die Electricität in der Medicin," 1866, p. 174 et seq.

to the neck and the other to the perinæum, after tannin, coffee, and tartar emetic had been unsuccessfully employed for several hours.

Those who attempt to produce artificial respiration in emergencies are frequently unfamiliar with the motor point of the phrenic, and therefore apply the pole in the neck indiscriminately. A medical acquaintance informs us that an attempt of this kind which he made in a case of opium poisoning proved instantaneously fatal to the patient. Under ordinary methods the patient was recovering, but in order to expedite the progress, faradization was tried. One pole was placed on the ribs, and the other somewhere in the neck, in order to find the phrenic nerve. Immediately the patient ceased to breathe, and no further treatment availed to resuscitate her.

This case, so far as we know, is unprecedented. It is explicable only on the theory that the shock of the sudden closure of the current near the nervous centre destroyed the waning life by concussion.

This unique and unfortunate case should not deter any physician from resorting to the electric method of artificial respiration in all cases where it is indicated, any more than the equally unique case of blindness produced by the galvanic current (recorded by Duchenne) should deter us from galvanizing the eyes and face.

Meyer records a successful result in a case of threatened death from exhaustion after diphtheria.*

Friedberg † succeeded in restoring a child of four years, asphyxiated by chloroform, by this method, combined with compression of the diaphragm.‡

Many failures have been made in the attempt to produce artificial respiration by faradization, because the operators were ignorant of the true method of application, or were not sufficiently persevering.

We have twice failed to resuscitate dogs that were narcotized by chloroform, although the applications were begun in less than a minute after the heart ceased to pulsate.

We failed also in a case of opium poisoning in an infant six weeks old.

Some remarkable results have been reported where life was saved by faradization around the neck and chest, kept up by intervals for many hours.

Dr. Allan McLane Hamilton, from a number of interesting experiments undertaken to test the utility of electricity in asphyxia, concludes as follows:

1st. That it is useless to expect good results if five minutes have elapsed since life appeared extinct.

* Op. cit., p. 431.

† Quoted by Meyer, op. cit., pp. 431, 432.

‡ Irritation of the phrenic nerve might be readily combined with Howard's method of artificial respiration.

2d. That the current should be applied faithfully and steadily, one pole being placed on the ensiform cartilage, the other on the base of the skull or over the tracks of the great nerves of the neck.

3d. That the faradic and interrupted galvanic currents are the best.

4th. That the current should be applied some time after respiratory movements have become regular.*

On December 28th, 1893, a child, aged six, was brought to our office with a large nævus materni or erectile tumor upon the cheek. She was chloroformed and needles introduced into the enlargement, preparatory to the electrolytic action of the current, when suddenly the respiration ceased, the pulse became imperceptible, and the only evidences of life were very faint and convulsive heart-beats. A faradic apparatus was at hand and one pole was immediately placed at the junction of the clavicle and the outer border of the sterno-cleido-mastoid muscle, and a vigorous current applied. Evidences of returning vitality were seen almost immediately, and within a few moments the heart was again beating regularly.

The question arises whether in this case the result was due to the electric application, or, as some might claim, did the heart, unaided, resume its normal action? The question as to the influence of electricity on the heart through its action on the pneumogastric is certainly a very interesting and a very important one. It has been claimed that in chloroform narcosis electricity will do more harm than good, since its tendency is to stimulate still further the inhibitory function of the vagus. Our experience, however, is that ordinary external applications affect the inhibitory fibres of the vagus that go to the heart in no such degree as they affect the accelerating fibres which in great measure constitute the branches that supply the respiratory organs. The very remarkable effects of the faradic current in keeping up the respiration in cases of opium poisoning are known to all. In one case of this kind that we saw, where the current was continuously employed for six or eight hours, the respiration would sink to two or three a minute, and the heart-beat manifestly weakened whenever the action of the current was interrupted.

Immediately on resuming the current the respiration would increase to eight per minute, and as the effects of the opium gradually wore away, the frequency of the respiratory act increased.

Now, in this case and in others of a like character that have fallen under our observation, it is fair to conclude that the current affected the accelerating fibres of the vagus controlling respiration, and not to any considerable extent the inhibitory fibres controlling the action of the heart. In chloroform poisoning, of course, a different condition of things prevails. The heart is under sedation, and any increase of the inhibitory effects of the pneumogastric might be dangerous. Fortunately there is little danger

* "Electricity as a Means of Resuscitation," American Practitioner, October, 1872.

of this in the use of the induced current, at least in ordinary percutaneous applications.

According to Von Ziemssen, who made many carefully conducted experiments by means of cardiographic tracings, induced currents have absolutely no influence on the frequency or force of the cardiac contractions, and from that fact the erroneous conclusion has been drawn that induction currents were valueless in threatening death from heart-failure. The facts are that electricity does good in increasing respiratory activity, the strength of current necessary for this purpose being insufficient to materially interfere with the movements of the heart, through its action on the inhibitory fibres of the pneumogastric that control it. Dr. George F. Shrady reports the case of a boy where death was imminent after the administration of chloroform. Respiration ceased and the pulse could not be felt, but through prolonged artificial respiration the life of the patient was saved. This confirms the report of the Hyderabad Commission, "that it is of primary importance to keep track of the respiration in administering chloroform; if this is kept up the heart will give no trouble."

Resuscitation of New-Born Children.—Successful experiments in the resuscitation of new-born children have been made by Schulz and Pernice. The latter succeeded in three out of five cases. In one of his cases the child was born to all appearances dead. Restoration was accomplished in half or three-quarters of an hour by the alternate use of the warm bath and faradization of the phrenic nerve.

Legros and Onimus * have experimented on animals—rats, dogs—with a view to bringing on resuscitation during syncope from loss of blood. They used the galvanic current, placing the negative pole in the mouth and the positive in the bowels.

We have treated several cases of suspended respiration. A new-born babe was to all appearances dead; faradization of the phrenic nerve resulted in decided manifestations of life for a few moments only. In the case of a lady who was in a state of asphyxia—from a subcutaneous injection of morphine—faradization of the phrenic nerve excited respiratory movements which were repeated some twelve or fifteen times after the current ceased to pass. We did not succeed in saving the patient.

* Gaz. des Hôp., No. 53.

CHAPTER XXXI.

EXOPHTHALMIC GOITRE.

In considering this strange and intractable disease we shall enter into no speculations as to its pathology, for the reason that all explanations of the phenomena that attend it are in the main conjectural. Neither shall we take time in discussing its etiology or its well-known symptoms, for these can be found in every text-book on neurology, with little variation of detail. The evidences of pathologic anatomy have thus far been so thoroughly negative that we are left to the symptoms alone for guidance in treatment.

These are, however, so positive and suggestive as to afford ground for a rational therapeutics, the end of which must be to regulate and give tone to nerve force, and to equalize the circulation.

In an experience including the treatment of fifty-seven cases* of exophthalmic goitre, we have been enabled to clinically study the disease very thoroughly, and form an opinion as to the benefits to be derived from certain methods of treatment not altogether in accord with prevailing opinions. In short, we hold that the prognosis in this disease is better than is generally believed, and if our results have been more satisfactory than others that have been reported, it has been due to a more rational use of electricity, which has been our main reliance, and greater thoroughness and persistency in its application.

While we by no means exclude the administration of drugs in the management of this disease, they are in our hands regarded as supplementary to the chief remedy, and subject to changes according to the indications in each individual case. The surprising lack of unanimity of opinion in regard to the efficiency of medicinal treatment is due to the fact that not only have those drugs that have proved beneficial in some cases failed to do good in others, but sometimes a drug that has in one case proved palliative has in another seemed to do harm. Iron, for example, is a universal remedy that is perhaps in the majority of cases fully indicated and is well borne, but we have occasionally found it to be productive of unpleasant symptoms even when anæmia existed, and have been compelled to discontinue its use. The statement of Von Graefe, that iron is useless in the height of the malady, but that it does good when a certain amount of improvement has occurred, is an observation of value, and founded upon an extensive experience.

* New York Medical Record, September 30th, 1893.

Our own experience has not been very favorable to the use of quinine, strychnia, or arsenic, and we now rarely administer them, and we believe the iodides often do more harm than good.

Belladonna has been highly recommended, and is undoubtedly of value. Carbazotate of ammonia we have used in but one case, but discontinued it after ten days, on account of the gastric disturbance that it seemed to occasion. Digitalis is by some believed to be useless in this disease, on the theoretic ground that it directly stimulates the muscular fibres of the cardiac vascular system. While the value of this remedy is now well recognized, there still exists much difference of opinion as to the method of its action. It has been regarded as a tonic, a stimulant, and as a sedative. The latter view, as is well known, was taught by Trousseau long ago, who held that it occasioned contraction of the superficial blood-vessels, thus producing diuresis, very much on the same principle as the action of fright or cold. In a recent discussion * Professor Crocq held that digitalis was not a sedative nor a cardiac tonic any more than alcohol is a tonic to the brain. It is simply a stimulant. Another view is that digitalis acts on the pneumogastric and sympathetic nervous system, thus regulating the action of the heart. By one the remedy is believed to act only on the left heart, by another on the right heart as well, retarding the action of both. But whatever theory is accepted, obstinate experience will not wheel into line at the command of any theory, however plausible.

On the theory of the stimulant and tonic action of digitalis we hesitated for a long time to use it in this disease, but when we finally came to put it to the test of actual trial we were most agreeably disappointed in the results, especially when combined with certain other remedies to which allusion is made further on.

If the heart seems abnormally strong in exophthalmic goitre, this is not by any means always the case. Very frequently there is enfeeblement of the myocardium, and digitalis is in many cases useful in slowing the rapid systole associated with it. The condition of the heart thus becomes improved by the physiologic rest it obtains through prolongation of the diastole.

Yet, like iron, digitalis may under certain conditions prove not only useless but harmful; but like iron, and especially in combination with iron, it possesses undoubted value. In what may be termed sthenic cases, where the excitability of the heart is great without enfeeblement, digitalis is certainly contra-indicated, and one such case occurred in our experience. In this case good results were obtained by substituting veratrum viride for digitalis.

Strophanthus has received high commendation, and on theoretic grounds it is recommended in preference to digitalis. While both tend to lengthen the interval between the contractions of the heart, strophanthus

* Academy of Medicine, Belgium, January 28th, 1893.

is supposed to contract the calibre of the arterioles in less degree than digitalis, and is to be preferred as not increasing the work of the heart to the same degree as the latter.

In conjunction with digitalis or strophanthus and iron, ergot and bromide of zinc seem to us to be distinctly valuable, and we have no hesitation in saying that a combination of these remedies will more nearly fulfil the indications in the majority of cases of exophthalmic goitre than any other single remedy or combination of remedies. There are probably to be found few, if any, who will not accord to electricity an important place among the remedies indicated in exophthalmic goitre, and unlike some others mentioned, it cannot, if judiciously used, do harm even in those cases where it does no good.

Gowers, who does not in general accord to electricity a very high place in therapeutics, yet says that in this disease it is followed in many cases by a distinct fall in the frequency of the pulse (amounting to 10 and even 20 beats per minute), and sometimes by a slight diminution in the size of the thyroid. In one case he observed the pulse fall from 90 to 72, a lower rate than had been counted during the preceding two years.* He adds, however, that such effects are usually transient, although repeated applications certainly sometimes cause a slight degree of permanent improvement. He has not seen more than this.

Even such results as Gowers describes are not to be despised, but the difficulty with his efforts, and with others who have written upon this subject, is the utter inadequacy of the strength of current used, and above all, so far as our observation goes, in the incomplete and haphazard way in which the applications are administered. Gowers would use a weak galvanic current, sufficient to cause merely a slight tingling of the skin, while others who have written extensively upon the subject are content with two or three milliamperes. These authorities do not seem to appreciate the fact that in the therapeutic use of electricity they are dealing with a hide-bound body which offers such a resistance to the passage of the current that our ingenuity is taxed to its utmost in order to overcome this resistance and get into the body a sufficient quantity of electricity to appreciably affect the cerebro-spinal system and the nervous system of vegetative life, the pneumogastric, the great sympathetic, including the vaso-motor system of nerves. These large current strengths cannot, of course, be used with small electrodes applied in the ordinary way over the region of the sympathetic and vagus in front of the neck, and from the mastoid process along the inner border of the sterno-cleido-mastoid muscle to the manubrium sterni. Here, although the current strength should be much higher than is usually recommended, it is rarely possible to exceed ten or fifteen milliamperes. For the greater strength of current, large electrodes, preferably of sculptor's clay, should be applied both to

* "Diseases of the Nervous System," p. 1214.

the back of the neck (cilio-spinal centre) and solar plexus. With electrodes in this position we have frequently used as high as sixty milliamperes, and with results the most beneficial.

We do not, however, recommend such apparently heroic treatment. Idiosyncrasies vary, and there is probably no remedy to the effects of which there is a more varying degree of susceptibility than to electricity. Every case is a law unto itself, and should be studied independently, with the exercise of judgment and common-sense in its management.

But if our results in the treatment of this disease have been exceptionally good, we attribute it in part to the fact that we have not confined our efforts to the use of drugs and the galvanic current alone, but have in many instances combined with these methods the most thorough and persistent treatment by the method of general faradization. While the methods of Eulenberg and Gutman in using simple localized faradization in the vain attempt to affect directly the sympathetic, and the faradization of the precordial region by Vigoroux and Charcot, may possibly do some good, they cannot compare in efficiency with general faradization, a method which has been abundantly tested and which rests upon a sound physiologic basis. While, therefore, we consider electricity of more importance than any other remedy in the treatment of this disease, yet in many cases the most rigid and conscientious observance of certain fixed rules in regard to eating and drinking, and the avoidance not only of excess in every department of mental and physical hygiene, but even the repression of ordinary and legitimate emotion and passions, become very essential. For the majority of these cases of exophthalmic goitre we are indebted to the kindness of the various members of the profession, most of whom have watched with interest the progress of the cases and have noted both the successes and failures.

We do not propose, however, to relate the failures nor to report in detail the cases (only too many in number) which experienced only partial and incomplete relief. Some absolute failures occurred, but not many. It is rare, indeed, that through the combined method of hygiene, diet, drugs, and electricity, the disease fails to be in some degree favorably influenced, for out of these cases there were but three that received no benefit whatever, and these were not even temporarily relieved.

Twenty-seven of these cases were benefited, some of them in very great degree, others only slightly. Some of those that were much benefited relapsed and received further treatment with good results, while others have been lost sight of and their subsequent history is unknown. In fairness, however, it must be said, that while the most persistent treatment failed to do more than slightly improve many of these cases, some of them, which otherwise possibly might have been benefited, discontinued treatment after a comparatively short period. Fourteen of these cases either fully or approximately recovered, records of which can be found in the New York *Medical Record*, September 30th, 1893.

While it is quite evident that in this disease the sympathetic is at fault, it is open to question whether the dilatation of vessels, which are such important factors in causing the thyroid enlargement and exophthalmus, is of a passive nature, due to paralysis of the sympathetic, or of an active nature, due, on the contrary, to an irritation of the dilator fibres which run in the sympathetic.* Accepting either theory, we find ample ground upon which to base indications for the use of the galvanic current. In case we accept the irritant theory, the very powerful sedative effects which may be obtained from the remedy is a sufficient explanation of the *rationale* of its use; while the fact that both physiologic investigation and clinical experience have shown that electricity is the remedy *par excellence* for most forms of paralysis, quite clearly points to its use in cases where there is actual paresis of the nerve itself. In addition to the hyperæmia of vessels as a cause of exophthalmus, there may be also accumulations of fat in the cellular tissues of the orbit, which is probably the main cause in certain cases why the protrusion of the eyes still remains prominent after a decided amelioration of every other symptom.

The latest views are that this disease is greatly dependent on disease of the thyroid gland itself, and a non-elimination of some toxin which poisons the whole nervous system. This theory of hyperthyroidation is held by Maude,† Rehn,‡ Greenfield,§ Starr,‖ and others. It still remains a question, however, whether the disease of the thyroid is primary or secondary and consecutive to nervous shock. On the theory of the thyroid origin of the disease, the results obtained by the direct application of the faradic current are intelligible. Mechanic effects alone might thus do good, and we have lately had under observation a case where the static spark applied to the thyroid greatly ameliorated the symptoms.

* The suggestion that the arterial dilatation is due to irritation of the dilator fibres is offered by Benedikt, based upon the experiments of Bernard, Schiff, Ludwig, and Loven.

† Brain, 1894.

‡ Journal of Laryngology, London, July, 1894.

§ British Medical Journal, December 9th, 1893.

‖ Medical News, New York, April, 1897.

CHAPTER XXXII.

MISCELLANEOUS MEDICAL DISEASES.

Sequelæ of Acute Diseases.—The sequelæ of several acute inflammatory diseases, and especially of diphtheria and cerebro-spinal meningitis, are of well-known severity and persistency. It is generally understood also that electricity in some form may perhaps be indicated in such conditions, particularly in diphtheria, and its use, which is occasionally attempted, has been followed by more or less benefit. We are quite sure, however, that the profession at large, in city as well as country, have a very inadequate idea of the vast benefit accruing from the use of this remedy in these cases.

Diphtheria.—Our first experience in the treatment of the sequelæ of diphtheria by electricity dates back some fifteen years, when we saw an obstinate case of paralysis of the vocal chords and the larnygeal muscles. The symptoms yielded readily to treatment, and the many cases that we have treated since yielded results too striking to admit of any doubt as to the efficacy of the remedy.

Dr. Dahlerup describes a case of cardiac paralysis occurring in a lad who was recovering from a diphtheritic attack.

The action of the heart became very rapid, but irregular and weak. Dyspnœa was present, together with cyanosis and orthopnœa, but the area of cardiac dulness was not increased.* Some improvement followed the administration of stimulants combined with digitalis, but at the end of a week the patient collapsed and died. Although the case was said to be one of progressive diphtheritic paralysis of the heart, it is not difficult to believe that the prompt and proper use of electricity might possibly have saved life.

Cerebro-Spinal Meningitis.—The symptoms that follow an attack of cerebro-spinal meningitis differ very widely both in character and gravity. We may have, first, incurable organic changes resulting in total blindness and entire loss of hearing, or the symptoms of a milder type which may be much benefited by treatment.

Typho-Malarial Fever.—When we come to consider the sequelæ of either typhoid or malarial fevers, we shall not, as a rule, find the same gravity or diversity of symptoms that often confront us subsequent to the acute stages of diphtheria and cerebro-spinal meningitis.

Convalescence is, however, occasionally very tedious, and we have re-

* British Medical Journal, September 27th, 1879.

corded not a few such cases where the tonic effects of general faradization and static electrification in hastening returning strength were most distinctly marked.

The differential indications for the use of the two currents in the sequelæ of the diseases under consideration may be concisely formulated as follows:

1st. For the relief of the various paralytic symptoms that follow diphtheria, whether cardiac or of the voluntary muscles, the faradic current is almost always, if not invariably, indicated. In the sequelæ of typho-malarial fever the faradic current is also chiefly indicated.

2d. The galvanic current here is not only less effective than the faradic, but is frequently useless, and occasionally harmful.

3d. While localized faradization may prove sufficient in cases where the symptoms are mild and restricted in extent, general faradization should be used where the paralysis is more general and constitutional symptoms are manifest.

4th. In the treatment of the sequelæ of cerebro-spinal meningitis the galvanic current, and generally by the method of central galvanization, is indicated.

Sequelæ of Sunstroke.—During seasons of protracted and excessive heat, a very large number of persons, especially in our cities, are more or less injured, either by the general depressing influence of the continued high temperature, or by some special exposure, without being, in the ordinary sense of the word, sunstruck. Those whose nervous system has been exhausted or disordered by the excessive use of stimulants and narcotics, by debilitating diseases, and especially by overlabor or excitement of the brain, are most liable to be thus affected.

Injuries thus produced may be manifested by every variety of nervous disorder—spinal irritation, insomnia, neurasthenia, neuralgia, epilepsy, nervous dyspepsia, hysteria, paralysis, and, not unlikely, positive insanity.

The majority of such cases never know the exciting cause of their symptoms until, perhaps, it is indicated to them by the physician who inquires into them. In a number of cases that have been under our care for the above symptoms the solar heat was a prominent if not a principal cause.

The symptoms may appear and reappear for months and years after the original attack. There is little doubt that there are through society thousands of such cases of various grades, many of whom have never suspected the nature of their malady. The solar origin of the symptoms which we have mentioned may be suspected not only when, as is very frequently the case, they can be traced to some definite exposure, but also when they are observed to be peculiar to the summer, remitting wholly or partially in winter, or to be especially aggravated by exposure to the sun, and to be experienced only during the daytime.

Our best results with electricity have been obtained in these cases by a combination of the two methods of electrization, general faradization and central galvanization, varied in some cases by galvanization of the pneumogastric and cervical sympathetic. Excepting those cases which, by some peculiarity of temperament, or as a peculiar result of the disease, cannot bear electricity, the electric treatment works admirably, whether used alone or in connection with internal medication. In the use of the galvanic current it is rarely desirable in these cases to exceed a current strength of ten milliamperes, and more frequently five will prove sufficient. Arsenic we give in the form of granules, $\frac{1}{50}$ of a grain each, before meals. We use also zinc in the form of oxide or phosphide, and fat in the form of cod-liver oil emulsion.

Cerebral and Spinal Congestion.—An exceedingly interesting point in the consideration of congestion of the nerve-centres is the discrepancy between the observed symptoms and the authoritative statements, in regard to the necessary and constant relation of certain symptoms with that condition. In pathologic conditions of the brain and spinal cord, more perhaps than with other organs of the body, it is difficult, nay utterly impossible, to associate a long list of distinct symptoms with some change or tendency to change of structure, and say that they invariably exist as effects and cause. What we term distinct variations from the physiologic conditions of the great nerve-centres, so markedly and undeniably run into and overlap each other, are so frequently as it were intertwined that it is hard for the most careful observer to do more than to arrive at approximately correct conclusions as to the actual pathology. Irritation and congestion of the cord may coexist. Congestion of a severe and chronic character may simulate actual sclerosis, and hysteria associated with a mild form of either irritation or congestion may give rise to symptoms of anæsthesia and such decided impairment of electro-muscular sensibility as completely to mislead the practitioner and suggest the existence of serious organic disturbance.

Prognosis and Treatment.—The relief that is afforded by electrization in the ordinary forms of passive spinal and cerebral congestion is quite constant and reliable.

Galvanization of the brain, spinal cord, and sympathetic are of course to be used, and should be attempted with more or less thoroughness according to the indications of each individual case.

General faradization, however, should not be neglected. There are very few cases that will not receive benefit by its judicious employment.

Anæsthesia.—Anæsthesia is derived from *α*, privative, and *αἰσθάνομαι*, to perceive, and therefore literally signifies a deprivation of sensation. It is a symptom of some organic or functional disease of the central or peripheral nervous system. The kinds of anæsthesia are as various as are the nerve ramifications, and the symptoms that accompany it are modified by the locality and causation of the disease. All forms of anæsthesia, as of paralysis of motion, may for the sake of convenience of description be classified under these four general divisions: Constitutional, central, peripheral, and reflex.

There are five kinds of sensibility, all of which are, of course, modifications of general sensibility, and all of which may become diminished by disease:

1. *Tactile Sensibility.*—This is the form which is most frequent and best appreciated. Diminution or loss of this sense is usually known as anæsthesia.

2. *Sensibility to Temperature*—heat and cold.

3. *Sense of Pressure or Weight.*

4. *Sense of Pain.*—This is quite distinct from tactile sensibility, with which, on superficial observation, it is often confounded. The loss of this sense is called analgesia. These different kinds of sensibility may be very unequally affected by disease. One form may be entirely destroyed, while the others remain intact. Thus, while tactile sensibility is perfect, the prick of a needle, when thrust into the flesh, is not felt. In such cases there is analgesia, but not anæsthesia.

5. *Farado-Sensibility.*—This form of sensibility appears to be sufficiently distinct to entitle it to special mention. Farado-sensibility may be quite active when tactile sensibility is much diminished.

The diagnosis of anæsthesia, except in very delicate cases, is sufficiently easy.

The degree of normal sensibility to tactile impressions varies widely in different parts of the body. It is necessary to bear this fact in mind and to make experimental trials on persons in health, in order to arrive at correct conclusions in cases of disease.

The use of the compasses, according to the directions of Dr. Weber,* will enable one to determine in a very accurate manner the condition of the sensory functions in health and disease.

Thus, when the two points of a pair of compasses are placed upon the inner surface of the last phalanx of the finger, they need to be separated but one line in order to give two impressions, while, in the middle of the thigh, the points of the compasses need to be distant from each other some fifteen to twenty-five lines in order that two impressions may be received.

Sensation in the tip of the tongue is more acute than in any other part of that organ, for two impressions are received when the points of the compasses are separated by only half a line; and it will be found that, in the face, this sense of acuteness diminishes as we recede from the mesial line.

Electro-Diagnosis.—There is a method of determining the relative elec-

* "De Pulsu, Resorptione, Auditu et Tactu, Annotationes anatomicæ et physiologicæ," Lipsiæ, 1834.

tro-sensitiveness of the two sides of the body that we have found very convenient and reliable, and sufficiently delicate except for those cases when the anæsthesia has extended over the entire system. This consists in the application of the faradic current by means of a brass ball, or other metallic electrode, attached to one of the poles of a faradic apparatus. The other pole of the apparatus may be placed at the feet of the patient, or at the coccyx, or at any indifferent point, as may be convenient.

Different points of the body, on both sides, are alternately touched with the brass ball, perfectly dry, very lightly, and with a mild current. In order to test the sense of pain, the ball should be covered with a moist sponge, so that the current may penetrate the epidermis. In this way a very slight difference of sensibility, especially of the upper and lower extremities, can readily be detected. By gradually increasing the power of the current up to the point of endurance, the extent of the anæsthesia can be ascertained with tolerable accuracy. One great advantage of this method is that the same apparatus with which we treat the disease can be used to diagnosticate it, and to mark the progress from day to day.

Treatment.—When the anæsthesia is very limited in its extent, and the general health of the patient is otherwise good, localized electrization is of course indicated. As a matter of fact, however, very many anæsthetic patients, whatever may be the cause on which their symptoms depend, are more or less debilitated, and are benefited by the constitutional tonic effects of general electrization. In cases of anæsthesia that are dependent on lesion of the central nervous system, central galvanization is sometimes indicated. Obstinate cases of a localized character are well treated by the electric brush. Anæsthetic patients will generally bear strong currents in proportion to the extent of the anæsthesia with benefit and without injury. Some temperaments that do not feel the current during the application may yet experience unpleasant reactive effects.

Prognosis.—The prognosis in anæsthesia, waiving for the moment all questions of causation or pathology, is usually very favorable, and beyond comparison more favorable than that of paralysis of motion.

One reason for this difference is that anæsthesia is an earlier symptom of organic disease of the nervous system than motor paralysis, and is therefore sooner treated. But we continually observe, even when the two conditions coexist, as is so frequently the case in central, spinal, and peripheral paralysis, that the anæsthesia yields much sooner and far surer than the paralysis of motion.

The discussion of the interesting physiologic questions suggested by these observations, though somewhat enticing and suggestive, does not come within the scope of the present work.

Intermittent Fever.—According to Tripier * and others since, the electric bath and static electricity have been used in certain cases of intermit-

* "Manuel d'Electrothérapie," etc., 1861, p. 581.

tent fever, both in England and Sweden, and occasionally with satisfactory results. The efficacy of the preparation of quinine in malarial disease has, however, destroyed most of the interest that might otherwise have attached to electricity in its therapeutic relation to fevers.

In certain chronic conditions of intermittent fever, where quinine and other internal medication have proved unavailing as a means of permanent relief, we have seen undoubted benefit arise from general faradization and the use of static electricity. It undoubtedly acts in this case like any other stimulating tonic without any special influence on the malarial poison.

The treatment of intermittent fever by electricity in the Medical Clinic of Genoa, directed by Professor de Renzi,* has given very good results.

Disease of the Supra Renal Capsules (*Addison's Disease*).—Our knowledge of the pathology of Addison's disease is very incomplete. In a large proportion of cases the bronzing of the skin and the peculiar cachectic condition of the affection are preceded by organic lesion of the supra-renal capsules.

Cases are not wanting, however, in which post-mortem examinations have revealed no anatomic lesion of the capsules, notwithstanding the previous existence of the most marked and severe characteristics of Addison's disease.

We have treated several cases of Addison's disease, and in one at least the amelioration of the symptoms through general constitutional electric treatment was quite remarkable. The case was presented before the then New York Medical and Library Association—not as a cure of disease of the supra-renal capsules, but as one of the very best illustrations of an extraordinary influence over nutrition.

Most of those present acknowledged the amelioration of the man's symptoms to be the result of the treatment, but doubted whether there was or had been disease of the capsules. For two years afterward the patient lived and enjoyed during the time all the vigor that had resulted from the use of electricity. Suddenly, and without apparent cause, his strength failed him, and within twenty-four hours he died. A post-mortem was obtained which substantiated the original diagnosis. The capsule of one kidney had entirely disappeared, leaving in its stead some calcareous remains. The other capsule was situated on the internal border of the kidney a little below its normal seat, and was composed of a cheesy-like substance—characteristic of the disease.

The specimen was presented before the members of the New York Pathological Society.

Diabetes.—The supposed relation of this symptom to the disease of the brain suggests the propriety of treating it by galvanization of the sympathetic and of the brain and spinal cord.

* Annali Univer. di Med.

Dr. William Dickinson,* who has made post-mortem examinations of the brain and spinal cord of five diabetic patients, found the following peculiar morbid changes, which were nearly similar in all:

1. Dilatation of the arteries. This was the earliest symptom.

2. Degeneration of the nervous matter.

3. Cavities produced large enough to be seen without the microscope, and which contained products of nervous decay.

4. These contents become absorbed.

These changes were found near the arteries and throughout the spinal cord and encephalon, but especially in the medulla oblongata and pons Varolii.†

These investigations were confirmed by a most distinguished authority in nervous pathology, Dr. Lockhart Clarke.

Besides these pathologic observations, there are two general considerations which might be adduced in favor of the theory that diabetes is essentially a nervous disease.

In the first place, it appears, in some instances at least, to be brought on by excessive mental excitement or worry. That it may be produced by concussion of the brain is, we believe, conceded. That there is a relation between diabetes and the base of the brain has for some time been more than suspected.

Secondly, the results of some of the therapeutic measures would seem at least to indicate that this disease may be favorably influenced through remedies that affect the nervous system. Prof. Austin Flint ‡ published reports of two or three cases of diabetes that were decidedly benefited by bromide of potassium.

Experience is the best and only test of the strength of these facts and considerations. The experiment of central galvanization—including the brain, spinal cord, and sympathetic—is surely worthy of a faithful trial, especially in the early stages of this affection. This treatment would be none the less indicated if, as some suppose, the pathologic changes found in the brain and spinal cord of diabetic patients are merely the result of the disease.

Experimentally faradization of the liver might also be tried.

Semmola § has found both temporary and permanent results from faradization and galvanization of the pneumogastric. In some cases both the quantity of urine and of sugar were diminished. It may be remarked that it would be difficult to galvanize the pneumogastric without also affecting the sympathetic.

* Medical Times and Gazette, March 19th, 1870.

† The relation which has been established by Calvi between diabetes and pruritus of the vulva, which is a nervous affection, would seem also to speak for the nervous character of the former disease. (See Damon's "Neuroses of the Skin," 1868, p. 25.)

‡ American Practitioner, January, 1870.

§ Quoted by Althaus, op. cit., p. 582.

It is yet too early to offer positive opinions in regard to the electro-therapeutics of this disease, but we have records of cases not a few where decided amelioration has followed electric treatment.

In the case of a lady beyond middle life, seen with Dr. Charles L. Dana, where diabetes was complicated with locomotor ataxia, the symptoms all greatly improved under persistent central galvanization (20 milliamperes) combined or alternated with general faradization or static electrification.

Cirrhosis of the Liver.—The pains that accompany this disease may be relieved by various electric applications, and it is possible that the disease might be arrested, in some cases at least, provided the treatment was begun early and faithfully carried out. We have known several cases to be somewhat benefited in this way.

Dropsical Effusions.—Dropsical effusions are susceptible of improvement by the electric currents, even when they depend on incurable diseases of the heart, liver, or kidneys. Galvanization and faradization may both be tried with strong currents.

In œdema of the lower limbs we have found both galvanization and faradization temporarily and sometimes permanently efficacious.

Bright's Disease.—Theoretically, local galvanization through the region of the kidneys and central galvanization ought to be of service in the early stages of Bright's disease. The nutrition of the kidneys might thus be improved directly and indirectly.

We have not yet experimented as much in this direction as we could wish, but in one case in which we had the co-operation of Dr. Judson C. Smith, an expert in urinary analysis, persistent, powerful, and long-continued faradization by means of broad electrodes placed over each kidney resulted in most gratifying results. Both albumin and casts decreased in uch a marked degree that at times they were not detectable, and the general health of the patient is now excellent.

Dr. H. J. Pratt, of Denver, Colorado, reports a case of Bright's disease where the galvanic current applied over the dropsical abdomen and general faradization resulted in relief of the dropsy, and in a diminution of the amount of albumin and of the hyalin casts.

Hay Fever (*Summer Catarrh—Rose Cold—Autumnal Catarrh*).—We have made researches in this strange disease, and have shown that the nervous system has more to do with it than has been supposed. We have treated several cases of the disease during the attack by external galvanization. In one case considerable and in the other case very decided relief was obtained. Electrization is worthy of a trial, since in a certain proportion of cases it will undoubtedly afford some relief.

Acute Diseases—Fevers—Convalescence.—General faradization and central galvanization might be used in acute diseases much more than they have been.* When quinine, iron, etc., are used, these methods of electri-

* See New Remedies, vol. iii., No. 3, p. 226.

zation should be used both for their sedative and their tonic effects. That the pulse and temperature, when abnormally high, can be reduced by general faradization and central galvanization we have abundantly established by many observations, and the greater tonic effects of these methods of using electricity are now conceded everywhere.

The introduction of these methods to the treatment of acute and subacute diseases offers a great field for enterprising general practitioners.

Dr. Glax treated thirty cases of typhoid fever by galvanization of the cervical sympathetic, and succeeded in reducing the temperature and diminishing the fever.

In convalescence from any acute disease, general faradization and central galvanization are a great assistance, and have been considerably used for that purpose by ourselves and other observers.

Obesity.—Obesity has been treated by powerful faradization, with a view to produce absorption of the adipose tissue, and, it is claimed, with some success. The applications are directed through the abdomen.

Chronic Alcoholism.—Without attempting to consider the many symptoms associated with alcoholic poisoning, or attempting to define the possible pathologic changes that may appear in the membranes of the brain and spinal cord, we would here simply call attention to a certain impairment of motor power in the lower extremities. This loss of power simulates paraplegia, but as a rule is only partial or incomplete.

It is, however, sufficiently distinctive to deserve the term of "alcoholic paralysis," and is indicative of a condition more rooted and severe than the familiar general muscular and nervous debility that afflicts the habitual drinker. While in many cases of alcoholic paraplegia it is evident that certain pathologic peculiarities must exist, such as chronic meningitis of the cord, on the one hand, and, on the other, thickening of the membranes of the brain and spinal cord, together with a wasting of their substance, it is in other cases as certainly evident that no such structural change is present. On no other supposition can we account for the rapidly and permanently beneficial effects that so frequently follow the use of electrization in cases of alcoholic paraplegia.

Ozone and Ozonized Oxygen.—When sparks of electricity pass between two metallic plates, a peculiar odorous principle is developed, which has been termed ozone (from ὄζω, to smell). This odor is observed during experiments with apparatus for static electricity, while the electricity is passing from a point, when a discharge from a strong battery is sent through a number of sheets of paper, and also after an object has been struck by lightning. As long ago as 1785, Von Marum observed that electrified oxygen gave forth an odor much like that which is observed after a lightning stroke. This odor was usually described as "sulphurous." Mr. Schönbein, who, in 1840, first called formal attention to ozone, first discovered that it appears at the positive pole in the electrolyzation of water

The observer also found that this peculiar odoriferous principle can be preserved in glass vessels for a very long time. The odor may be prevented from appearing by raising the temperature of the liquid to a boiling point, and it may be at once neutralized by the addition of quite small quantities of pulverized charcoal, tin, zinc, iron, lead, antimony, bismuth, or arsenic, by a little mercury, or by introducing into the substance red-hot platinum or gold. It is produced by the slow oxidation of phosphorus. It is disengaged from solutions of a number of the salts, and from diluted nitric, phosphoric, and sulphuric acids.

Mr. Gann concluded, from his experiments, that this odor may be evolved from all metals, provided they are so treated as not to become oxidized or to combine with other metals.*

Tests.—The test for ozone proposed by Schönbein was a paper moistened with a solution of iodide of potassium and starch. The ozone sets free the iodine and gives the starch a deep-blue color.

General Properties.—Ozone is active, intensified oxygen. Like oxygen, it has a powerful oxidizing action. It is about half as heavy as oxygen, and, at a temperature of 290° (Cent.), is changed back into ordinary oxygen. It is only soluble in oil of turpentine.

Ozone exists in the atmosphere in greater or less quantity, which is believed to vary with the atmospheric conditions, and to exert a definite and powerful influence on the health, although precise and satisfactory demonstration of the nature and extent of the laws of this influence is yet wanting.

According to the experiments of Professor Schönbein, Messrs. Martiguer, Marignac, De la Rive, Becquerel, Frémy, and others, it would appear that ozone is only a peculiar form of oxygen produced by electricity —a change analogous to that which the solar rays bring forth in chlorine —and that its presence in certain quantities is essential to health. According to Dr. Boeckel, Professor Schönbein, and Dr. Billiard, the presence of cholera or malaria is attended by the absence of ozone.† It is possible that ozone has more or less share in the variations of the physical conditions that have been ascribed to changes in the conditions of atmospheric electricity. Ozone is found to be especially abundant in the atmosphere after a thunder-storm. It is also supposed to be produced by decay and the growth of plants. It destroys the impurities of the air miasms by producing oxidation. It has been estimated that "a volume of air containing $\frac{1}{6000}$ of ozone will purify 540 volumes of putrid air." In the arts ozone has been utilized for bleaching and disinfecting.

Physiologic and Therapeutic Effects of Ozone.—The physiologic effects

* "Lectures on Electricity," by Henry M. Noad, London, 1844, p. 232.

† "On the Influence of Variations of Electric Tension as the Remote Cause of Epidemic and Other Diseases," by William Craig, 1864, p. 424. See also Cornelius Fox on "Ozone and Antozone" for a résumé of what is known of this subject.

of ozone have been studied both on man and on animals. It is believed that the bracing and inspiring effect of a clear, crisp, and sparkling morning is due in part to the great amount of ozone in the atmosphere.* When it is held in combination with oxygen or common air, it acts much like oxygen, but more powerfully. It affects the pulse, the respiration, and the circulation, in various ways, according to the quantity taken and the temperament of the individual. In this respect it behaves like electricity. It has been thought that ozone is formed in the body from the contact of oxygen gas with the blood, and there are those who believe that it is absorbed with the oxygen in the air, and is carried into the blood, where it takes part in the process of oxidation.

There is a possibility, if not indeed a probability, that electricity, in its passage through the body, generates ozone in very minute quantities, through the electrolytic and other changes that it produces, and the theory that the beneficial effects of electrization are in part due to the ozone thus generated has some plausibility. But on all these subjects very little is known. Experiments made in the laboratory with ozone, artificially prepared, are highly suggestive. Catarrhal symptoms and attacks, much resembling epidemic influenza, are produced by long breathing air laden with ozone. It is stated that it would be difficult to distinguish between the symptoms of influenza and the symptoms of an overdose of ozone. Experiments on animals have shown that irritation of the mucous lining of the throat and nostrils, with febrile symptoms and congestion of the lungs, may be quickly excited by breathing air containing a large percentage of ozone. If animals are for a long time subjected to ozone they perish. In their susceptibility to it, however, they vary widely. A rabbit, breathing air mingled with $\frac{1}{2000}$ of its weight in ozone, has died in two hours. Mice, breathing air about $\frac{1}{6000}$ of ozone, have died immediately. Rats are more susceptible than guinea-pigs, and guinea-pigs are more susceptible than rabbits. Pigeons are quite tolerant of ozone, and frogs are proof against it, provided they have abundance of water. Birds are specially tolerant of this agent, as might naturally be inferred, since, in the higher strata of the air, where they fly, ozone is more abundant than near the earth.

A convenient apparatus for the inhalation of ozonized oxygen is that of Siemen, which consists of a glass tube lined with tinfoil leaves that are connected with the current from a powerful helix, and slightly separated from each other, so that in passing from one to the other the current is interrupted with sparks. Through this tube the oxygen passes from an iron receiver, and ozone is developed by the action of the current at its interruptions. By this apparatus fifteen per cent. of the oxygen may be converted into ozone. A glass apartment may be constructed on the same

* Dr. Baldwin, Am. Jour. Med. Sciences, October, 1874, gives observations that oppose this theory.

principle, in which the patient may sit for a long time and slowly breathe in a natural manner the diffused ozonized oxygen. Dr. C. Leuder,* of Berlin, has successfully experimented with the inhalation of ozonized oxygen in the treatment of wounds, and has found that in malaria and various conditions associated with impure blood and depraved nutrition, its corrective and tonic effects are very decided. Others, both abroad and in this country, have studied the therapeutic effects of ozone with encouraging results.

The Electric Light in Disease.—E. de Renzi, of Naples,† Kellogg,‡ and others, have made interesting experiments in order to determine the therapeutic properties of the incandescent electric light. The former, in a remarkable paper, gives the results of his experience on this subject. The effects noted in pulmonary phthisis were: Great increase in organic oxidation, body weight, urinary secretion, and respiratory power; diminution in febrile movement and slow diminution of bacilli in sputum. Baths of four lamps of 32-candle power, under the bedclothes, are administered for from two to six hours.

In 31 observations there was an immediate and marked diminution in the temperature, pulse, and respiration. The amount of hæmoglobin and the body weight increased. The author, from bacteriological as well as clinical experiments, believes thoroughly in the curative properties of light. Kellogg greatly prefers the incandescent electric light over the arc light for therapeutic applications.

* "Das unreine Blut und seine Reinigung durch negativ-electrischen Sauerstoff (Ozon)." Also, "Sauerstoff und Ozonsauerstoff, nebst ihrer Anwendung bei Verwundeten, nach einem im Berliner Inhalatorium gehaltenen Vortrage."

† Rivista clinica e terapeutica, Naples, April, 1894.

‡ Transactions Am. Electro-Therapeutic Association, 1894.

ELECTRO-SURGERY.

ELECTRO-SURGERY.

CHAPTER I.

HISTORY OF ELECTRO-SURGERY.

Electro-Surgery is that branch of electro-therapeutics which includes the electric treatment of the diseases commonly known as surgical.

Besides the many medical applications of electricity, all of which may be used for surgical diseases, it includes galvano-cautery and electrolysis, both of which may be regarded as peculiar to this department.

History of Electro-Surgery.—The history of surgical electricity, though to a considerable degree interwoven with the history of electro-therapeutics in general, is yet sufficiently distinct to entitle it to special consideration.

Electro-surgery was born in one of the darkest eras of electro-therapeutics, the decade just preceding the great discovery of induction by Faraday, in 1831. The distrust and neglect with which at this period especially electro-therapeutics was regarded by men of science were due partly to the reaction that inevitably followed the extravagant hopes that had been raised on the discovery and popularization of the voltaic pile at the beginning of the century; partly to the inconstancy and unreliability of the pile itself, partly to the almost absolute ignorance of the profession concerning the indications for, the effects of, or the methods of using electricity; and partly also to the fact that it was confounded with mesmerism, which, after creating absurd and widespread excitement, had fallen into deserved and permanent neglect.

It was in the middle of this era, in the year 1825,* when the cause of electro-therapeutics seemed hopelessly lost, that Sarlandiere † called renewed attention to this despised agent by proposing the employment of

* Two years previously (1823) Prévost and Dumas had attempted, with some success, the dissolution of calculi of the bladder in animals; and many years before some surgical diseases had been treated electrically, but the subject was not systematically studied until 1825.

† "Mémoires sur l'électro-puncture," Paris, 1825.

electro-puncture, in order to bring the current more directly to bear on the deeper tissues. The first experiments were made with static electricity.

The subject was afterwards studied by Magendie, who used electro-puncture with the galvanic current (galvano-puncture) in the treatment of various diseases. At first electro-puncture was used medically more than surgically. The treatment of aneurisms by this method was of a later date.

The idea of causing coagulation of the blood by galvano-puncture was originally suggested by Scudamore, and in 1831 Guérard, Pravaz, and Leroy d'Etiolles proposed the treatment of aneurism by this method, which was first practised by B. Phillips about the year 1832,* and afterwards studied by Liston.

In 1839 Schuster successfully employed electro-puncture for the treatment of hydrocele and other serous effusions, and in 1843 he reported his successes to the French Academy.

In 1839, and the year following also, Crussel, whose name is so prominent a figure in the history of electro-surgery, began his investigations on electrolysis.† His experiments excited little interest in the profession.

In 1843, also, Steinheil and Heider suggested the theory that the nerves of teeth might be killed by placing a platinum wire, heated by the passage of a galvanic current, in the cavity, and in 1845 Heider first successfully employed this method. He used for this purpose one very large element of Grove. The operation took but a few seconds.

In 1846 Crussel, whose name, as we have seen, is also to be remembered as the founder of electrolytic treatment, successfully removed by the heated platinum wire a "large fungus hæmatodes, situated in the frontal and ocular region."

In the same year Petréquin, of Lyons, obtained successful results in the treatment of aneurisms by galvano-puncture. The year 1846 may therefore be regarded as one of special significance in the history of electro-surgery. About this time also, the same treatment was used by Burci, of Italy.

In 1847 Bertani and Milani first treated varicose veins by galvano-puncture. In the same year Crussel published his method of treating ulcers by availing himself of the electrolytic powers of the galvanic current. This author observed that when two metallic plates are connected with the poles of a galvanic apparatus, and applied to the body, very different

* Erichsen's "Surgery," p. 513.

† Frommhold: "Electrotherapie mit besonderer Rücksicht auf Nerven-Krankheiten," Pest, 1865, p. 104.

The first experiments with electrolysis were made much earlier than this; since, according to Brenner, Mongiardini and Lando had used a needle-shaped electrode, connected with the negative pole (probably of a voltaic pile, which was then just coming into notice), for the treatment of gangrene. "Dell applicazione del Galvanisme alla medicina," Genovæ, 1803.

effects were produced at the two poles—the positive acting like an acid, and making harder the tissue; the negative like an alkali, and causing an increase of fluid. On the strength of this observation, Crussel treated ulcers and cancers by a flow connected with the positive pole of the apparatus, while the negative was in the hand of the patient. The result of this treatment was to cause a scab to form, which fell off, leaving the sore smaller and more healthful in appearance. Repeated treatment of this kind wrought cures.

In the same and the following year, Crussel formally called the attention of the profession to "the electrolytic method of cure." * For the treatment of strictures another method was subsequently investigated by Willebrand, Wells, Ciniselli, and has recently been revised by Scouteten, Mallez, Tripier, and others. In 1850 Marshall suggested and successfully employed the galvano-cautery in the treatment of fistulæ.

In 1852 Baumgarten and Wertheimer, with the co-operation of Malgaigne, successfully operated on an aggravated case of varicose veins in the arm.

In 1852, also, Ciniselli † first established by experiment that the alkalies appear at the negative, and the acids at the positive pole. His method of demonstration was to lay a piece of flesh across the edges of two vessels filled with distilled water, and alternately connecting each of the vessels with a pole. The acids were found in the vessel containing the positive pole, and the alkalies in the vessel containing the negative. The piece of flesh was shrunken and burned.‡

In 1853 Ellis first used the heated platinum wire for cauterization of the cervix in inflammations and ulcerations. In this same year Hall successfully treated a case of ununited fracture by galvano-puncture.

A great and important impulse was given to galvano-cautery by Middeldorpff, who in 1854 published his celebrated work on the subject.‖

In 1855 Demarquay removed a swelling of the submaxillary gland by galvano-puncture. In the same year, Vergnés and Poey published their experiments on the removal of poisonous metals from the body by the electro-chemic bath.

In 1856 Boulu caused resolution of tumors in a number of cases by magneto-electricity, applied by means of metallic disks. Two cases of swelling of the parotid gland were in this way entirely cured. In the same year Meding extracted mercury from a patient who had long suffered from mercurial poisoning, by means of the electro-chemic bath.

* "De Electrolytische Heilmethode." Neue Med -Chir. Zeitung, 1847, No. 7. Med. Zeitung Russlands, 1847 and 1848. Quoted by Meyer, op. cit., p. 474.

† "Dell' azione chimica, dell' electricita," Cremona, 1852.

‡ Brenner: "Untersuchungen und Beobachtungen auf dem Gebiete der Elektrotherapie," Bd. ii., p. 265.

‖ "The Galvano-Caustic," Breslau, 1854.

In 1858 and 1859 Zsigmondi published the result of his successful experience with galvano-cautery after the system of Middeldorpff. In 1859, also, Delstanche, Lehmann, Burdel, and Thevissen reported successes in the treatment of hydrocele by farado-puncture.

In 1861 Braun and Von Gruenewald introduced the galvano-cautery into gynecology, where it has since been employed for the removal of polypi, excision of the cervix, and so forth.

Both in the extent and the variety of his operations in this department Middeldorpff far surpassed all his predecessors. He devised a powerful, though somewhat bulky apparatus, as well as various burners and loops for operating on different parts and organs of the body.

In 1867 Althaus * revived the attention of surgeons to the surgical powers of electricity by reports of successful experiments in the treatment of nævi and tumors of various kinds by electrolyzation.

In later years extensive researches have been made in nearly all the prominent departments of electro-surgery by the authors of the present treatise.† The results of the researches are recorded in this section. Experiments made in those departments of electro-physiology bearing on electro-surgery have already been recorded in the section on Electro-Physiology. During the same period the various departments of electro-surgery have been studied by Althaus, Von Bruns, Byrne, Groh, Neftel, Duncan, Newman, Voltolini, Caldwell, Prince, and, following Apostoli's investigations, a host of workers too numerous to mention have done excellent and original work in this department.

Surgical Compared with Medical Electricity.—In comparing this history of surgical with that of medical electricity, we observe a number of interesting points both of similarity and of contrast. Surgical is much younger than medical electricity, dating, as we have seen, from 1825. In neither department has the progress been uniform or consistent. Eras of extravagant expectation have been followed by eras of indifference, although with surgical electricity the contrast has been much less marked than with medical. The interest that was aroused by the introduction of electro-puncture in 1825, of electrolysis and galvano-cautery in 1846–47, was followed by a reaction of negle t that allowed the whole subject to sink into nearly absolute forgetfulness. The progress of surgical even more than of medical electricity was impeded by want of convenient and reliable apparatus, and by this difficulty is explained the fact that so few workers entered this most promising field. While the number of experimenters in medical electricity, both in the profession and out of it, and in various countries, is very large, including very many of the ablest writers of modern medical literature, the practice of distinctly surgical electricity has been confined

* "Tumors and other Surgical Diseases," 1867.

† "Clinical Researches in Electro-Surgery." By A. D. Rockwell, A.M., M.D., and George M. Beard, A.M., M.D. William Wood & Co.

to a few, and the authors by whom it has been really advanced could be counted on one's fingers.

Surgical, unlike medical electricity, has been studied and pursued mainly by men of science, and the progress that has been made in it has been much more frequently the direct result of scientific observation and experiment. Those physicians who have made eras in medical electricity have done so by improving, developing, systematizing, and introducing to the profession methods of treatment which either by charlatans or others had been substantially known and practised before them. Sarlandiere, Stenheil, Heider, and Crussel, on the contrary, first suggested and employed as well as introduced to the profession electro-puncture, galvano-cautery, and electrolysis.

Another important distinction is this, that nearly all the surgical diseases for which electricity is employed have been treated with more or less success by other methods, while in many of the medical diseases in which electrization has been most successful it has been the chief, and in some the only dependence.

Finally, it should not be forgotten that the surgical successes achieved by electricity have been of great service to electro-therapeutics in general. A surgical operation appeals to the eye and to mechanical skill, while medicine appeals to the higher and rarer qualities of reason and imagination. Many who fail to comprehend a complex medical fact or principle may be fascinated and carried to enthusiasm by whatever strikes the senses. Hence we find that the suggestion of electro-puncture in 1825 revived an interest in electricity that its purely medical applications failed to sustain, and from that time to the present the fortunate operations of galvano-cautery and electrolysis have aroused the attention of many who had no faith in and no comprehension of the remarkable powers of electricity over nutrition.

Temperament of the Patient Less Important in Surgical than in Medical Electricity.—In medical electricity, as we have seen, the results of treatment largely depend on the temperament. Some can bear almost any amount of electric treatment, others can bear but a little, and others still can bear none at all. We have seen in the chapter on Neurasthenia and Allied Affections that symptoms for which electricity is peculiarly adapted, and over which its greatest victories are obtained, sometimes refuse to yield and are indeed aggravated when any form of electricity is used by any mode of application, for the reason that the temperament of the patient contraindicates electricity. Temperaments that will not bear electricity at all or but little are quite frequently found, especially among the better classes. In surgical diseases that are treated by distinctively surgical applications of electricity the temperament need not usually be taken into account. Electro-surgical operations are of a thermal or chemic character, and are not dependent for their success on the idiosyncrasy of the patient. We have seen, furthermore, that the electro-susceptibility of patients may appear either in the form of farado-susceptibility or galvano-susceptibility—some who can bear and be benefited by the faradic current cannot bear the galvanic, and *vice versa*. In electro-surgical operations the possibility of these special idiosyncrasies need not be considered. It is true that patients behave very differently after electro-surgical operations, that some suffer from irritative fever and others do not, and these differences of effect may very likely be due to differences of electro-susceptibility, but such differences are not usually of sufficiently serious importance to require consideration.

CHAPTER II.

ELECTROLYSIS—ITS NATURE AND GENERAL METHODS.

THE definition and derivation of electrolysis, as well as its general laws and phenomena, have already been given (see Electro-Physics, Chapter IV.). Its physiologic relations have also been presented in considerable detail (see Electro-Physiology). It remains for us here to speak only of electrolysis in its surgical relations, and to describe the rules and methods of the various operations in which it has been found of service. Electrolysis in surgery is, however, so closely dependent on electrolysis in physics and physiology that no one can intelligently utilize and explain it in operative procedures who does not also understand its physical and physiologic relations.

The term electrolysis is a general one, and signifies decomposition by electricity. As such it applies to the electric decomposition of inorganic as well as organic substances, and of animal tissues, whether in health or in disease, living or dead. Practically, however, the term is now pretty well restricted, in electro-therapeutic language, to the electric decomposition of morbid growths, or to parts affected by chronic inflammation, by means of some form of needle electrodes, and although more or less electrolytic action takes place in all applications of the galvanic current externally or internally, yet the term, when applied to any electric operation, is understood to imply that electrolytic action was the leading effect sought for, and that it was obtained by needles, or at least by some form of metallic electrode more or less pointed at the extremity.

On the other hand, when electrodes with very large surface are used, with a view to chemic effect, and the transfer of fluids with absorption, the process is called catalysis. Catalysis or cataphoresis depends, in part at least, on electrolysis, and the distinction between the terms, which has been observed by electro-therapeutists, is practical rather than scientific.

Theory of Electrolysis of Morbid Living Tissue.—For electrolysis, living as compared with dead tissue has the twofold advantage that its solutions are warmer and therefore better conductors, and that it is capable of the processes of absorption.

When needles connected with the poles of a galvanic battery are inserted into a tumor, a threefold action is produced:

1. *Decomposition of its Fluid Constituents.*—Hydrogen and alkalies, soda, potassa, etc., go to the negative, and oxygen and acids to the positive. The special character of these electrolytic phenomena will depend

on the character of the tumor, and the rapidity of the action will be proportioned to the relative amount of its fluid constituents. As the body is mostly composed of water holding salts of potash, soda, etc., in solution, it is a good electrolyte, and in most of the conditions of disease undergoes rapid decomposition. Scirrhus and fibroids, when hard and firm, require considerable strength of current, and are electrolyzed with comparative slowness. Erectile tumors, which are almost entirely of fluid composition, can be electrolyzed very rapidly. Although electrolytic action takes place at both poles when inserted in tumors, as when inserted in inorganic substances, yet this action on the whole appears to be the more vigorous and more effective for causing absorption and disintegration at the negative pole, and in practice this pole is usually found to be the more efficacious, although successful results are obtained by the positive pole or by both combined. Epithelioma, being largely composed of water, also decompose rapidly.

Reasoning from what we know of the electrolysis of inorganic substances, it is proper to assume that in the electrolysis of a malignant tumor, for example, the many chemic substances of which it is composed undergo manifold combinations and recombinations, the precise nature of which cannot well be fully divined, and the practical effect of which in causing discussion of the tumor can only be determined by extended clinical experience.

2. *Absorption.*—Absorption may be hastened both by the chemic changes that take place, and also by the mechanically irritating effect of the needles and the transference of the anions and cations. This absorption takes place both during and after the treatment. In some cases it is not at all observed during the operation, but goes on slowly for weeks following. Stimulation of absorption is especially marked when electricity acts on hydrocele and cystic tumors.

3. *Disintegration and Atrophy.*—As a result of the decomposition and absorption, and associated with them, the tissues become dried, separated, shrivelled, and the tumor decreases in bulk and may entirely disappear. All these processes, or rather the effects of these processes, may be distinctly observed during the electrolysis of any small wen, mole, nævus, or wart, both during and after the operation. Shortly after the needle is inserted, the growth will be seen to change in color; the skin soon begins to shrivel and contract, like an apple when it is baking. The next day the growth will be still smaller, and perhaps nearly or entirely obliterated.

Apparatus for Electrolysis.—Electrolytic action is chiefly obtained by the galvanic current, although there is little question that the faradic current (both the electro-magnetic and magneto-electric) has more or less electrolytic power, and the magneto-electric current has been used in electro-plating.

It has been shown that for the purposes of galvano-cautery quantity with moderate tension was required, and that this was obtained by a few large elements; for the purposes of electrolysis tension with moderate or fair quantity is required, such as is obtained by a considerable number of elements of medium size (see chapter on Ohm's Law in Electro-Physics).

Any of the galvanic batteries described in the chapter on apparatus can be used for electrolysis, and when available the Edison low-pressure street current with its voltage limited to 110 combines convenience, constancy, and safety.

Methods of Testing the Electrolytic Batteries.—Batteries may be approximately tested with a view to ascertaining their comparative advantages for surgical operation by the amount of deflection they cause to the needle of the galvanometer of known construction; by the rapidity and amount of decomposition which they cause in simple compounds, such as acidulated

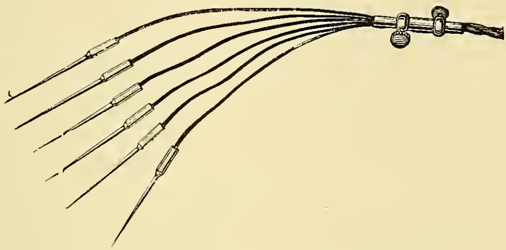


FIG. 174.—Conductor for Electrolysis.

water, iodide of potassium, or common salt; and by their capacity for heating platinum wire.

An approximate test for the qualities that are needed in electrolytic operations in the absence of a galvanometer is found in the decomposition of iodide of potassium. The rapidity with which this yields to the current of a battery, and the amount of iodine evolved in a given time, very fairly indicate the capacity of that battery for electrolytic purposes.*

Needles.—For producing electrolysis in tissues beneath the skin fine needles of gold or gilded steel are used. The advantage of the gold is that it resists oxidation better than any other metal. Gold or gilded needles can, however, be used only with the negative pole, since with the positive they would be acted on. The conductors may be composed of two, four, six, eight, or more needles. The needles may be insulated with hard rubber, or collodion, or shellac for about one-third of their length,

* In experimenting with galvanic batteries care must be taken to avoid frequent or long-continued connection of the metallic portions of the electrodes, since, on account of the feeble resistance thus offered—metals being far better conductors than the human body—powerful action takes place in the cells (as is shown by the active evolution of gases, attended with a boiling or hissing sound), which, if allowed to continue, eats holes in and rapidly consumes the zinc.

so that when introduced into a tumor the skin may not be acted on and inflammation excited. Insulation, however, is only necessary in those cases where, as in subcutaneous nævi, it is desirable that the skin should not be affected by the current.

The shape of the point is of considerable importance. Round needles are introduced with difficulty. The bayonet-pointed needles are preferable. The common glover's needle, as sold in the fancy stores, we have found to be easier of introduction than any other form.

The conductor represented in the cut (Fig. 174) is of practical value.

This consists of a conducting wire, composed of a number of small wires twisted, with a number of branches, each one of which is so ar-

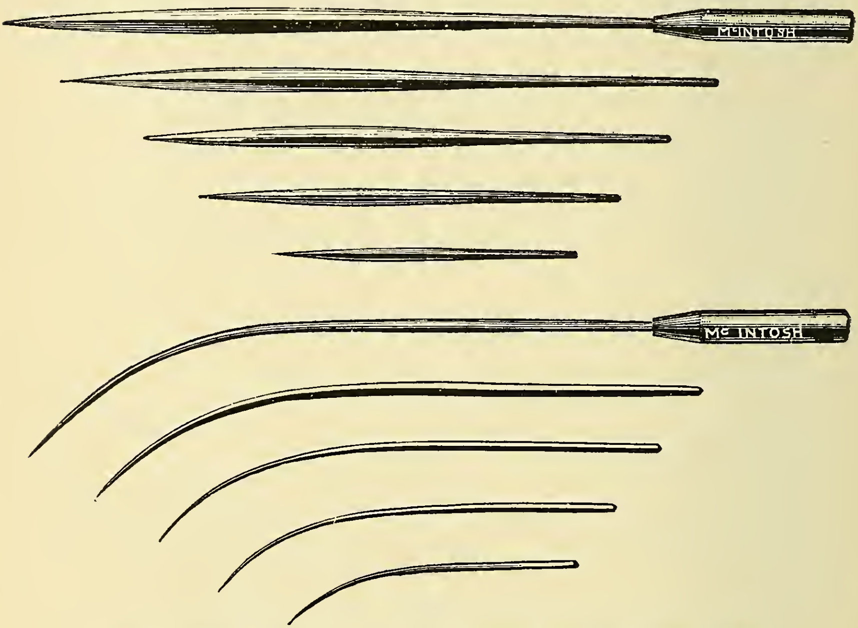


FIG. 175.—Straight and Half Curved Flattened Needles for Electrolysis.

ranged that it can be attached to a needle after it has been introduced into the part to be treated.

The advantages of this arrangement are that one needle or more can be used, and that the number can at pleasure be increased or diminished during the operation, and that the needles can be introduced in any direction. In the conductor which we have constructed, and which is represented in the cut (Fig. 176), the needles are united to the conducting wires by being inserted in miniature cups or cavities at the end of the wires.

Flexible Copper Wire for Connecting the Needles in Electrolytic Opera-

tions.—These needles (Fig. 176) are attached to connecting wires by fine flexible copper wire. Wire of this kind, it may be remarked, is a most convenient and almost necessary adjunct to an electrolytic case, and to the operating-room of the electro-therapeutist. It is useful for many purposes

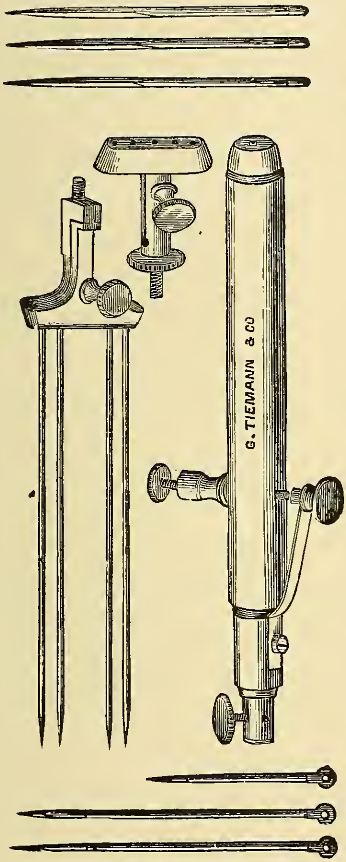


FIG. 176.—Needles for Electrolysis, with Rockwell's Needle-Holders.

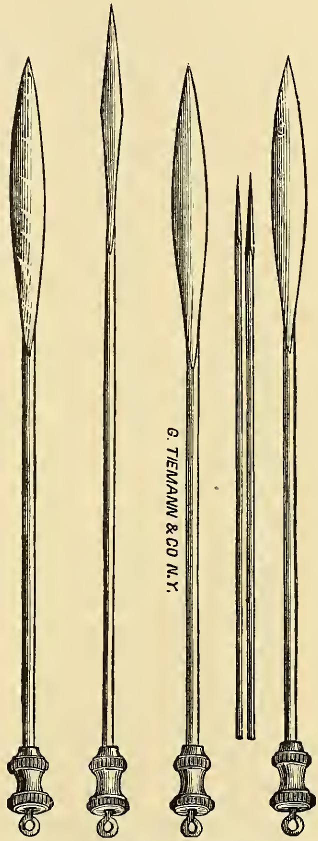


FIG. 177.—Long Cutting Needles for Electrolysis of the Base.

of connection, and when thumb-screws are out of order or broken off it very well supplies their place.

Dr. Murray, of this city, has employed needles insulated at both ends, leaving an uninsulated portion in the middle. He uses these needles in the treatment of hydrocele and cystic tumors. They are introduced so that the insulated portion is on the skin, and the uninsulated portion within the tumor.

Method of Introducing the Needles.—The skin in some parts of the body is quite tough, and needles go in with much greater difficulty than one might suppose. The method of introducing a hypodermic syringe is the best method of introducing needles for electrolysis. The skin may be pinched up and kept tense with the left hand, while the right pushes in the needles the required depth. If it is impossible or merely difficult to push the needles in as far as is needed, it is better to let on the current, and allow a little electrolytic action to take place around the needle. This will loosen it at the negative pole (though at the positive it will have the opposite effect, and bind it close and firm). The negative needle thus loosened can easily be pushed farther in.

The pain attendant on the introduction of the needles is, of course, best combated by full anæsthesia or by ether spray or by cocaine; but there are many cases where anæsthetics are hardly required, where ether spray cannot be conveniently used, and where it is desirable to diminish in some way the pain. A mixture of ether and carbolic acid in equal parts, first suggested to us by Dr. Sterling, has a positively benumbing effect on the part to which it is applied. The mixture can be localized to a very small spot, and the benumbing effect begins to be felt in less than five minutes, and lasts for fifteen or twenty minutes, varying with the amount used. It turns the skin a little white. The disadvantage in its use is that it sometimes makes a slight sore afterward.

The benumbing influence of the faradic current may be utilized for this purpose (see Electro-Anæsthesia).

Electrolyzing the Base.—We have occasionally treated malignant tumors of various kinds by a method of electrolysis which was termed by Beard working up the base, or electrolysis of the base.

The ordinary method of electrolysis does not suffice for malignant tumors. It will relieve the pain, but relief of pain can be obtained by simple external galvanization without any needles. It will cause a certain reduction in size, but this reduction is almost always limited, rarely exceeding ten or twenty-five per cent. In some cases, not the slightest perceptible reduction is caused, even by the most persevering use of electrolysis. When powerful currents are used, there must, of course, result more or less destruction of tissue near the point where the needles are inserted, and by successive operations the entire growth may be broken down, or may slough away after the operations are discontinued, and it is possible to extend the operations far into the base and surrounding tissues. Some of our first cases were treated in this way; but it is to the last degree awkward, tedious, and involves a great waste of time and force.

Method of Operating by Electrolysis of the Base.—The patient must first be fully etherized. The method of operating on a small tumor is first to insert the needle connected with the positive pole underneath the tumor and near the border. A similar needle connected with the negative pole is inserted also underneath the tumor, and, if possible, at some distance below the base of the growth, so that the point emerges on the opposite side. The current is now gradually let on, and the strength increased until the electrolysis becomes active, as will be indicated by the yellowish foam that appears at the negative pole, gradually loosening the needle. As the action increases, the negative pole may be slowly worked from side to side with a slight cutting motion, so as to undermine the tumor. The positive meanwhile remains *in situ;* it becomes firmly adherent through oxidation, and need not be removed until the close of the operation.

After the tumor falls off, through the undermining of its base, the base itself can be worked up in all directions with the needles, or with the harrow electrode that we have devised for this purpose. After the removal of the growth, it is well to change the position of the poles in working up

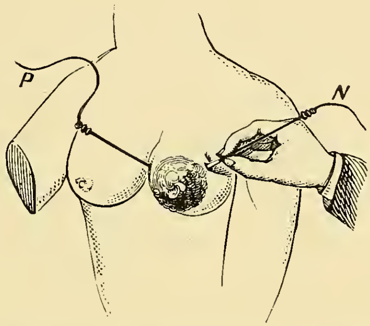


FIG. 178.—Electrolysis of the Base in a case of Scirrhus of the Breast. Large and long negative needle manipulated by the operator in the healthy tissue, some distance from the border of the tumor. Connection made by ordinary positive needle inserted near the base of the tumor.

the base, so that all parts of the surface may get the benefit of the action peculiar to both poles.

If the tumor is a large one, as an extensive epithelioma or scirrhus, it is better to have it first removed by the knife. The base can then be worked up in the manner just described.

The cavity after the operation has a charred appearance and alarms the patient and his friends unless they are forewarned.

The time required for an operation of this kind ranges between ten minutes to a half or three-quarters of an hour. Some swelling and œdema in the surrounding tissues follow the operation, but little or no pain, although the charred appearance of the cavity that has been thoroughly electrolyzed is sometimes quite formidable.

Instruments Required.—For this method of working up the base we have devised needles, or electrodes, Fig. 177, that are quite different from those employed in the ordinary method of electrolysis. The needles are long, spear-shaped, double-edged, and tolerably sharp, so that a slight cutting action may be combined with the purely electrolytic action. These needles are not insulated, except in that portion that is grasped by the hand in operating.

Theory of the Method.—Pathologic investigations seem to point pretty clearly to the view that cancer, whatever the diathesis may be, is in the beginning a local disease, and affects the adjacent parts and the general system by actual transfer of the cancer-cells.*

If we accept these views we must also accept the view that cancer, whatever constitutional treatment we adopt, should be treated locally, and by some method of local treatment that acts not only on the body of the tumor, but also and especially on the surrounding tissue, and that the earlier such treatment is used the better the prognosis.

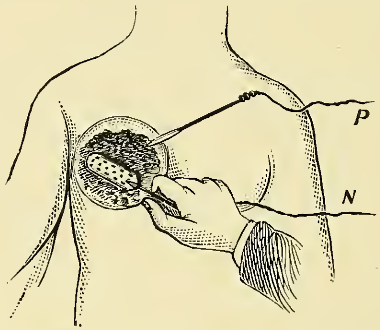


FIG. 179.—Electrolysis of the Base of a Scirrhus of the Breast after Removal of the Tumor by the Knife. Harrow electrode connected with the negative pole and long cutting needle with the positive pole.

When we remove the tumor and close up the wound, we leave the areola mostly untouched, and shut up the cancer cells in a soil best of all adapted to nourish them. Hence we need not wonder that the disease recurs either immediately in or near the place of removal, or that the cells wander to some distant part where another tumor appears after months or years.

The morbid or semi-morbid tissues that surround malignant tumors have been treated in various ways by caustics, in substance, by caustic needles, and by the actual and galvano-cautery. So far as we can learn from the experience of surgeons who have faithfully tried any one or all of these methods, the results are more satisfactory than the results of ordinary treatment by the knife or ligature.

The theoretical arguments that electrolysis of the base would produce more radical results than the use of caustics are based necessarily on our

* See " A Lecture on the Structure of Cancerous Tumors, and the Mode in which Adjacent Parts are Invaded," by Dr. Woodward, Assistant Surgeon, U. S. A. The Toner Lectures of the Smithsonian Institution, Washington, November, 1873. See also the admirable discussion on the subject by Drs. De Morgan, Hutchison, Paget, and others, in The Lancet for March and April, 1874.

ideas of the nature of the electric force and of the process of electrolysis. When electrodes connected with the two poles of a galvanic battery are inserted into the animal tissue, the vibrations of the electric force not only pass between the electrodes, but extend to a considerable distance in all directions from them, and much farther than the direct effect of caustics would reach.

Advantages of the Method.—1. Less liability to recurrence of malignant tumors.

2. Less hemorrhage than other methods of operating. The reason for this has already been explained—electrolysis coagulates the blood, constricts the tissues, and slightly cauterizes them. Ordinary parenchymatous hemorrhage is thus controlled in the most satisfactory manner, so that if a strong current is used, neither sponges nor styptics are required.

3. Less liability to shock. We form this judgment from protracted operations made on patients in various stages of debility, and in the extremes of life, infancy, and old age. We have not yet seen any effect at all suggestive of shock, after very long sittings under strong currents, even where sensitive localities were operated on. The electric current would indeed appear to be one of the very best antidotes to shock, and for a long time it has been known and used as a means of resuscitation.

4. It is followed by a more satisfactory healing than other operations. This fact has been observed markedly in several severe and hopeless cases, and has attracted the attention of all the surgeons who have seen the cases.

5. There is reason for the belief that the future will show that septicæmia and pyæmia are less likely to follow electrolysis than other surgical operations. It is more than probable that electrolyzation, like cauterization, constringes the absorbents so that they cannot absorb pus.

6. To all these facts must be added the consideration that many patients dread the knife—without reason it may be, and without common-sense; but patients are not expected to exercise reason or common-sense—and such persons are willing to submit to electricity, however employed.

The advantages of working up the base by electrolysis, as compared with working up the base by caustic, the actual cautery, or the galvano-cautery, are worthy of study.

Disadvantages of the Method.—1. It requires apparatus more or less bulky, and they require more or less experience in their management.

2. Electrolytic operations frequently require more time than operations with the knife or ligature, and in some cases the operation must be repeated.

If electrolysis produced shock, this element of time might, perhaps, be a serious one; but, inasmuch as it appears to act as an antidote to shock, and as the stimulus of the current allows us to prolong anæsthesia with safety, and as in many of the cases where electrolysis is used treatment by knife or ligature is contraindicated, this objection need not deter us from resorting to it.

3. The irritative fever that follows powerful and prolonged electrolytic operations is sometimes severe. The parts around the tumor operated on become more or less swollen, but are not usually painful, and this swelling also soon subsides.

It is proper to state that the ordinary method of electrolysis, if thoroughly used and repeated a sufficient number of times, may run into this method of working up the base, and in epithelioma, at least, may accomplish good results. The body of the tumor may be gradually broken and destroyed; and then, in successive operations, the needles may be made to work up the base and surrounding tissue. Groh,* of Vienna, has used this method with success in quite a number of cases of epithelioma, as well as of sarcomatous growths. We have used the same method in epithelioma, and with success. The method has, however, the sufficiently serious objection that it first wastes the time and strength of the patient on unnecessary treatment of the tumor, and is only successful in proportion as it falls back on the method of working up the base and surrounding tissue.

* "Die Electrolysis in der Chirurgie," Vienna, 1871. Groh has also treated sarcomatous growths by very prolonged electrolysis with mild currents. This method seems to have greater inconveniences, without any compensating advantages.

CHAPTER III.

GALVANO-CAUTERY.

Galvano-Cautery.—Galvano-cautery is cauterization by a resisting wire heated by the galvanic current. It is very often confounded with electrolysis; but as we have seen, electrolysis is the decomposition of a compound substance by means of electricity. A slight cauterizing action may indeed accompany electrolytic operations, but it is incidental merely, and is not a part of the electrolysis, nor the end desired.

It is a law of electricity that when it passes through a resisting wire it raises its temperature in proportion to the resistance of the wire and the quantity of the electricity. The wire thus heated is capable of producing cauterizing effects. Platinum offers a greater resistance to the passage of the electric current than any other metal except mercury and lead, and is therefore used in galvano-cautery. It will be seen at once that the electricity is not applied to the body, as in the various forms of electrization, but only the wire heated by the passage of the current.

Advantage of Galvano-Cautery over the Actual Cautery.—The one great advantage of the galvano-cautery over the actual cautery is, of course, the fact that the heat in the wire connected with the battery can be controlled at will. It can be let off and on, increased or diminished at pleasure and instantaneously. With the actual cautery such control is manifestly impossible.

Heat is heat, however obtained; and the heat of a platinum wire through which a current is passing has probably no advantage as such over the heat of a poker that has been thrust into the coals. The advantage lies simply in the fact that in the one case the heat is under the complete control of the operator during a long operation if necessary; in the other case it is not under such control.

Apparatus for Galvano-Cautery.—Galvano-cautery operations require batteries composed of a few large cells. Rarely are more than eight cells used, and the best batteries can be turned into one or two cells. The batteries employed in electrolysis or in ordinary galvanization are not available for galvano-cautery—*vice versa*, galvano-cautery batteries are of but little use in electrolytic operations or in ordinary galvanizations. The explanation is to be found in the chapter on Ohm's Law.

The galvano-cautery current is obtained directly from the ordinary galvano-cautery batteries or from storage batteries, sometimes called accumulators. Accumulators possess advantages over galvano-cautery batteries from the fact that they are thoroughly constant and do not have to be plunged into and out of the acid. Furthermore, an accumulator yields more than twice as many ampere hours as the ordinary cautery battery of the same size. In the large towns where the low-pressure street current is available, the storage battery is far preferable; but in the smaller towns not possessing this advantage, or where the cautery is used only occasionally, the galvano-cautery battery will answer the better purpose. Batteries

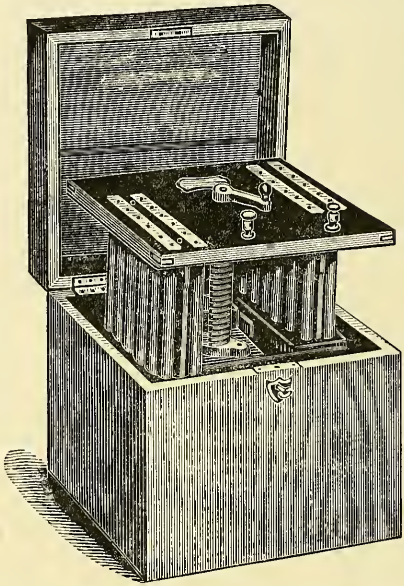


FIG. 180.—The "G. F." Cautery Battery (Van Houten & Ten Broeck).

for galvano-cautery that do good work are made by almost every manufacturer.

Those who make a large use of galvano-cautery will probably require two kinds of batteries—portable and stationary—just as they require portable and stationary faradic and galvanic apparatus.

An efficient cautery battery is represented in Fig. 180, consisting of the ordinary zinc-carbon elements. The current, which is regulated by means of a rheostat, is sufficient to heat all ordinary-sized electrodes and loops. The elements are readily raised and lowered by means of the crank on the top in the centre.

One of the most successful attempts to combine a suitable degree of strength with compactness and lightness has, perhaps, been made in the battery represented by Fig. 181. It is composed of but two hard-rubber cells, with elements of zinc and carbon—each cell measuring 3½ inches in length, 2½ inches in width, and will retain a number 19 platinum wire at a white heat for more than a quarter of an hour. The elements are made to move on small wheels horizontally, in their relation to the fluid in the cells. This is a great improvement on the old method of blowing with an air-bulb for the purpose of producing agitation of the fluid, and consequent increase of current strength, and seems to us to more thoroughly displace the battery fluid than any other method. For very prolonged operations this little battery is hardly sufficient, and should be replaced by the larger form, consisting of four cells.

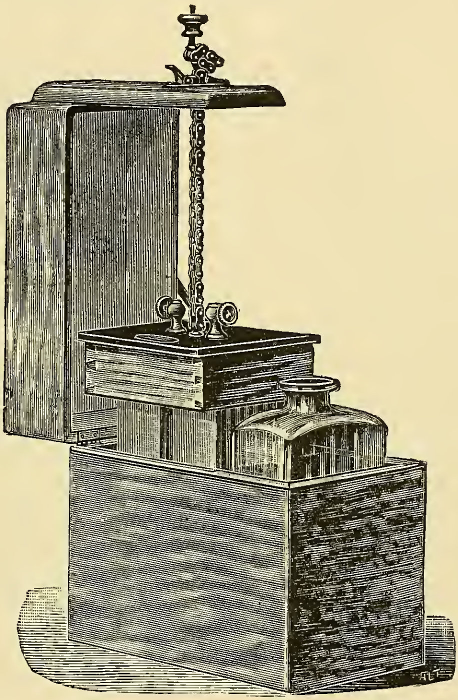


FIG. 181.—Galvano-Cautery Apparatus (Kidder).

Storage Batteries or Accumulators.—Storage batteries may be charged either from primary batteries or from an incandescent lamp circuit.

The Vetter current adapter (Fig. 182) furnishes a handy and clean method by which storage batteries can be easily and economically recharged from the incandescent light circuit and at very little expense.

The illustration shows the manner of charging a storage battery with the constant incandescent currrent by means of the Vetter adapter. *A* is the adapter attached to an ordinary electric-light fixture, with a 50-candle power lamp in the receptacle of the adapter. The charging posts of the battery are connected with binding posts 1 and 2 of the adapter by means of the two conducting cords.

The time required to charge the battery by this method depends entirely on the amount of current left in the battery and the capacity of the lamp. A 50-candle power lamp will charge at the rate of $1\frac{1}{2}$ amperes of current per hour; a 100-candle power lamp at 3 amperes per hour.

The principle of the storage battery is seen in Fig. 183. The plates are of cast lead covered with litharge, and it works on the principle of polarization. These plates are immersed in a jar containing water, acidulated with about twenty per cent. of chemically pure sulphuric acid. In order to charge the cell, it is necessary simply to connect the upright post marked

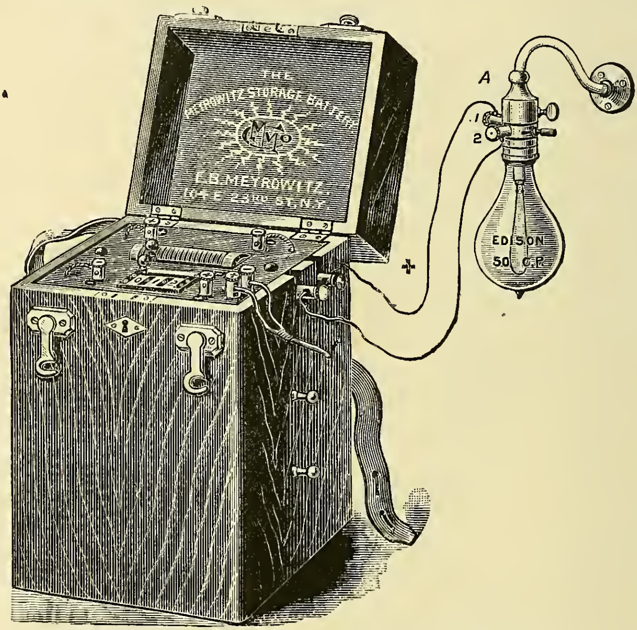


FIG. 182.—Storage Battery with Vetter Current Adapter.

+ with the positive pole, and the other with the negative pole of a few galvanic cells or with the incandescent light circuit, as illustrated in Fig. 182. When connected, the water in the jar is decomposed, oxygen and hydrogen respectively being deposited on the different plates of lead. In this way a so-called polarized current results, and on connecting the conductors with the upright posts through which the cell has been charged, a current of electricity is obtained sufficient to heat platinum to incandescence.

The durability and efficiency of a storage battery depend upon the care which it receives, and it can only be recommended where one is doing constant work in galvano-cautery. He who uses the cautery only at intervals will do better to depend upon the ordinary plunge galvano-cautery apparatus.

Care of Galvano-Cautery Batteries.—In order to attain the maximum of power from galvano-cautery batteries, and to keep them in good working order, much more care is necessary than in the case of ordinary batteries for galvanization.

The reasons for this are twofold:

1. The chemic action is very vigorous because the solutions are strong

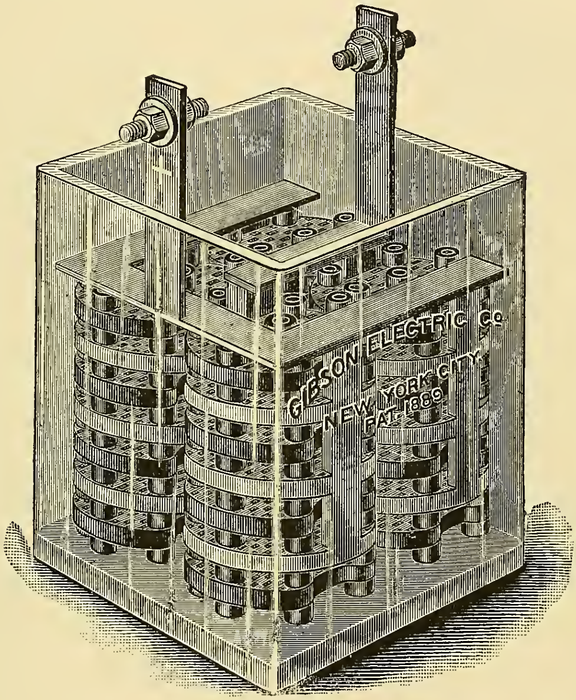


FIG. 183.—Storage Battery.

and the circuit is metallic throughout. In ordinary external galvanization or in electrolysis the resistance of the body interposed in the circuit is so great that only a small quantity of electricity can be evolved (see chapter on Ohm's Law); hence the zinc is not so rapidly consumed.

2. The galvano-cautery batteries—especially the portable varieties—have comparatively little reserve power. If the solution becomes old or the plates become corroded badly, the heat generated may be too feeble for important operations. It is therefore necessary frequently to renew the solution entirely, and not in part, as is so often done with ordinary galvanic batteries. With the portable zinc-carbon batteries it is a great advantage thoroughly to soak the carbons in tepid water after each operation.

A practical point of much importance is that when the zinc plates become much worn, and the distance between the carbon plates is correspondingly increased, the internal resistance of the batteries is greater and the power is diminished.

Accompanying Instruments.—In the operation of galvano-cautery a large number of burners, loops, and handles are used. These are of every variety and can be adapted by the operator to the needs of any special case.

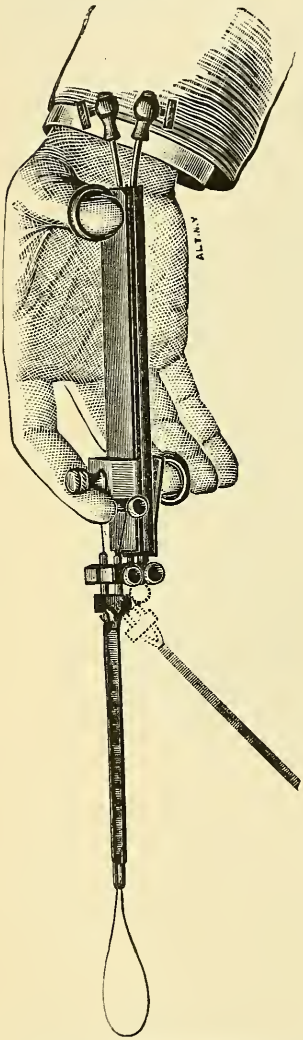


FIG. 184.—Galvano-Cautery Handle with Slide and Platinum Loop for the Bloodless Excision of Tumors, etc. (Kidder).

Uses of the Galvano-Cautery.—The special purposes for which galvano-cautery has been recommended and employed are the following:—

1. Removal of tumors of various kinds, in parts that are not readily accessible to the ordinary methods of extirpation—pediculated tumors of the larynx, polypi of the larynx, naso-pharyngeal space, external auditory canal, vagina, rectum, and uterus. Malignant tumors in any accessible position may be removed by galvano-cautery in order to avoid hemorrhage.

2. Amputation of diseased organs or parts of organs, like the neck of the uterus, the tongue, etc., as a palliative.

3. Cauterization of ulcers.

4. Cauterization of chronic inflammations of mucous membrane, in the urethra, nasal passages, conjunctiva, etc.

5. Cauterization of cancerous tumors to stop the hemorrhage.

6. Cauterization of the base and tissue surrounding malignant tumors that have been previously removed by the knife or ligature.

7. Cauterization of erectile tumors so as to cause coagulation, absorption, and in some cases sloughing.

8. Treatment of fistulæ, by cauterizing the fistula alone, or by cauterizing surrounding parts, or by cauterizing both the opening and the parts surrounding, or by opening the fistula.

9. Treatment of neuralgia by cauterizing and killing the nerve.

10. Treatment of prolapsus uteri by cauterizing with the burners the

vaginal walls, and thus causing inflammation, suppuration, and cicatricial contraction.

Advantages of the Galvano-Cautery.—The advantages of the galvano-

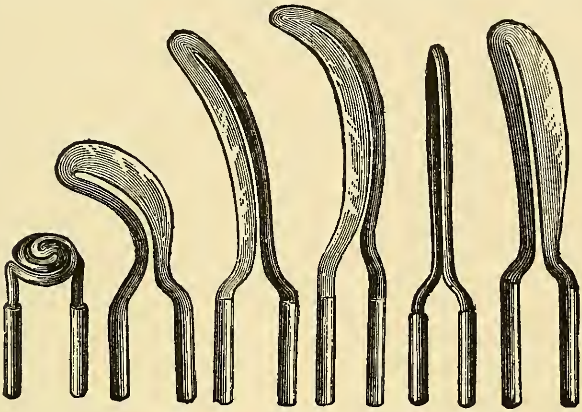
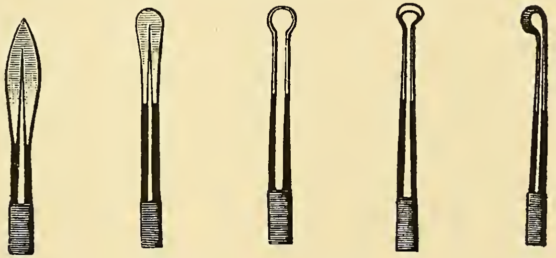


FIG. 185.—Heavy Platinum Cutters and Burners (Kidder).



1 2 3 4 5 6

FIG. 186.—Various Forms of Cauterizers.

cautery over the actual and potential cautery and the ordinary operations by cutting instruments, are these:—

1. It can be used on parts that are not easily accessible to ordinary instruments.

2. It saves all or nearly all hemorrhage.

3. It combines the after-cauterizing effect with the other results of the operation, as is sometimes desirable.

4. It is more sure in its action, and can be more accurately localized, especially in cavities, than the ordinary methods of cauterization.

5. It is but little painful after the operation, and is rarely or never dangerous.

6. It is followed, like electrolysis, by a more satisfactory healing than by the knife or ligature, and as after electrolysis there is less liability to pyæmia.

The one disadvantage of the galvano-cautery is the difficulty of managing the necessary apparatus.

This difficulty is now diminishing; the advances that have recently been made in this department will bring the galvano-cautery within the reach of all who are willing to devote the amount of attention which a new department must at first demand.

There is reason to believe that in the future, with accessible and compact appliances, the use of the galvano-cautery will be greatly extended. No one can expect to succeed with the galvano-cautery who is not to some degree a master of electro-physics.

Rules for the Use of the Galvano-Cautery.—1. For all large and important operations fresh fluid should be used in sufficient quantity, and the battery should be in all respects clean and in good order.

In the use of the galvanic current for ordinary galvanization, fluid needs entire renewal but rarely, and if an evaporation or waste reduce the strength, simply pouring new fluid into the old, or pouring in water alone, will answer to bring up the battery power to the necessary standard.

2. Before beginning the operation, the apparatus should be in thorough preparation. Our battery should be tested, and the handles and wires or knives should be carefully overhauled, so that there may be no chances of bad connection or bad working of the screws, wheels, or other appliances.

3. In all operations of importance it is almost indispensable to have an assistant, whose exclusive duty it shall be to immerse and take out the elements as may be required during the various steps of the operation, or to increase or decrease the strength of the current. The operator will have all he can do to control the instruments in his hands.

4. The strength of the current employed in the operation should be carefully adapted to the size and length of the wire-loop or knife that is used in the operation. If too great a quantity of electricity is used for the size and length of the wire loop, the wire may break before or during the operation—very likely very near the close of the operation, to the annoyance of the operator. If too little quantity of electricity is used, the loop or knife will not be sufficiently heated, and will not burn through the tissues, or if the tissues are divided, hemorrhage may occur.

As the loop grows smaller near the end of an operation, the quantity of electricity should be diminished by raising the elements somewhat in the solution, so that less surface may be exposed.

Accurate judgment in this regard can only come from careful and repeated preliminary experimentation, and from entire familiarity with the battery employed.

5. In the case of malignant growths of all kinds, the heated wire, loop, or knife should go sufficiently far beneath or around the growth to include healthy tissue. In amputation of the cervix, for example, the wire should be placed above the ulcerated or indurated part so as to remove

the entire cervix, and very much more if the disease extends far into the body of the uterus.

In some cases this would be impracticable, and then it is necessary to abandon all hopes of radical or permanent relief, and content ourselves with palliation merely.

6. In cases where the wire-loop is used, the traction on it by the wheel or other contrivance should be very gradual, and by intervals, so that the surfaces of the parts exposed may be thoroughly cauterized. The temptation is to make the operation brilliant and brief, by rapidly contracting the loop. Those operators who yield to this temptation may be annoyed by immediate or secondary hemorrhage.

7. When the shape and position of a part to be excised are such that a loop cannot be adjusted, a groove should first be burned around the part by the galvano-cautery knife (Byrne).

8. The wire-loop or knife should be accurately adjusted, and be perfectly in position before the connection is made and the current let on.

9. The loop should not be contracted until it has passed into the submucous tissues, and when passing through superficial or cellular tissue, the wire should not be brought to a white heat (Byrne).

10. In protracted operations, where delay is necessary between the different stages, the elements should be raised out of the solution when the current is not needed, so as to rest the battery and economize its force.

The current necessary is inversely proportional to the size of the wires used and the platinum tips of the electrodes. Five amperes of current will usually bring to incandescence the small electrodes used for nose, throat, ear, and eye work, but for large cautery knives and heavy wire thirty to forty amperes may be required.

Adaptation of Galvano-Cautery to Various Departments.—In the adaptation of galvano-cautery to any of the special departments, one needs to be guided by the general principles already laid down. The efficient contrivances and modifications of apparatus, and of modes of operating, will depend on the skill and experience of the surgeon.

Dr. Thomas Bryant, of London, has published the results of a large variety of experiments with this form of "bloodless surgery."

The cases of amputation of the cervix uteri with the galvano-cautery that have been attempted by the surgeons of the Woman's Hospital, with our assistance, have proved entirely satisfactory. In these cases, if the platinum wire be of sufficient size, and the cutting be done slowly, not a drop of blood need be lost.

The galvano-cautery has been used by ophthalmologists for the cauterization of granular lids, and inflammations and abscesss of the lachrymal ducts. By aurists it has been used for the removal of polypi and other tumors from the external auditory canal. By laryngologists it has been used for the removal of nasal and naso-pharyngeal polypi, for the cauterization of granular inflammations, for the cauterization and removal of various laryngeal growths, and for tracheotomy.

In the rectum the galvano-cautery has been utilized for operation on fistulæ and for the removal of piles. By general surgeons it has been used for amputation, and for the treatment of epithelioma and other malignant growths.

CHAPTER IV.

BENIGN AND MALIGNANT TUMORS.

THE success of the electrolytic procedure in benign and malignant tumors depends on the method used. One may fail by one process and succeed by another, just as in any other surgical operation. The tendency has been to be satisfied with the mere employment of galvano-puncture, without regard to the method, and to accept the results, whether favorable or unfavorable, as serving to settle the question of the value or uselessness of electricity in surgery.

In electrolysis everything depends on the method; and with the same method, skill, care, and thoroughness may succeed, when awkwardness, carelessness, and inattention fail utterly. The failure of electrolysis in any form of tumor—benign or malignant—is not to be counted a reproach until we know the actual method used and the character of the operator.

The errors that have been and are continually made in electrolytic operations begin and end, as we have seen, in ignorance or forgetfulness of the laws and facts of electro-physics and electro-physiology, and especially of the former. No one can be a scientific and successful electro-surgeon without also being more or less of an electro-physicist.

NÆVI—ERECTILE TUMORS—ANGIOMATA—WINE MARKS.

Nævi (erectile or vascular tumors) are both cutaneous and subcutaneous. The terms cutaneous and subcutaneous, however, simply indicate a difference in seat, but not in kind. The two forms are often associated, and the wide-spread dilatation of cutaneous vessels, attended with little swelling, that are commonly called "mother spots," are evidently similar in character to the subcutaneous variety to which Bell gave the name of aneurism by anastomosis. Erectile tumors may be either venous or arterial.

This variety of tumors may be treated by the ordinary method of electrolysis, with a good probability of success, provided the conditions of success are skilfully observed.

It is first of all necessary to understand that to cure all forms of erectile tumors electrolytically without leaving any scar or trace is simply impossible. In many cases, and notably in those of larger size, and which are partly cutaneous and partly subcutaneous, sooner or later destruction of tissue is requisite to bring about a cure; and destruction of tissue after electrolysis, like destruction of tissue after the use of other agents, is followed by cicatrization.

When the nævus is small and superficial, then a mild electrolytic operation may be followed by a shrinking of the tumor, and a rapid and permanent absorption of the *débris* without any scar; but such cases can hardly be said to constitute the majority. The scars following the electrolytic treatment of nævi may, however, rapidly disappear; at least the little patient may in time entirely outgrow them.

It is necessary to be understood, in the second place, that the electrolytic operations for nævi, as for other kinds of morbid growths, are usually sufficiently painful to require some form of local or general anæsthesia. It is almost absolutely safe to give ether to young children; and the operation, even though it be but very short and but little painful, can be conducted far more successfully when the child is anæsthetized than when it is not. With adults, and sometimes with children, local anæsthesia by ether spray is sufficient; but it is generally inferior to general anæsthesia. The struggles of the child to get free, its terror at the sight of the instruments, can all be saved by a carefully administered anæsthetic. The details of the operation differ with the site and character of the tumor. Success has followed the use of both poles in the tumor, or only one, while the connection is made by a sponge-electrode on some indifferent point. If the tumor be small, and but one pole is used, it is better that it should be the positive, since the clot formed at the positive pole, though small, is hard and firm. If the tumor be large, needles connected with both poles may be used. Whether one or more needles are to be used depends on the size of the tumor, but generally one needle connected with each pole is sufficient. If many needles are used, it is difficult to manage them; and some may fall out, and thus disturb the operation. It is better, as a rule, to take out the needle at different stages, and insert it in various parts, until the entire growth is acted upon. We have sometimes found it of advantage to reverse the current during the operation, so that all portions of the tumor may be acted on by both poles. Insulation of the needles is only required in the case of entirely subcutaneous tumors—where, as in the case of aneurism, it is desired to produce a coagulum (which may be slowly absorbed) without injury to the skin.

The length of the operation may range between five and twenty-five minutes, according to the strength of current used, the size of the needles, and the size of the tumor.

The great point in all electrolytic operations for nævi is to do just enough without doing too much. If the operation be not reasonably thorough, absorption will not take place, or the tumor may recur. If the operation be too extensive or prolonged, the destruction of tissue may be greater than is needed, and the subsequent cicatrization may amount to a least a temporary deformity. For very large and semi-cutaneous or semi-subcutaneous nævi, that exhibit a tendency to spread in all directions, it is necessary to place the needles at or near the base of the tumor, and in the surrounding tissue, among the enlarging and tortuous vessels, in a manner somewhat resembling the method of electrolyzing the base of malignant tumors. If such tumors are treated timidly, no good result will come, and the operation may be several times repeated without satisfaction. It is rarely necessary to use more than 50 milliamperes in these cases.

The advantages of the electrolytic procedure in nævi are these:

1. In small and superficial tumors, the cure may be effected with little or no scar. On the face and other exposed parts of the body, this advantage is very great.

2. In large nævi, and those which are partially or entirely subcutaneous, the liability of recurrence would be less, and probably the extent of the cicatrization would be less than after the ordinary method of treating these growths.

In these cases of subcutaneous erectile tumors, electrolysis is almost if not quite a specific, if used with care and judgment. It may, on the other hand, not only entirely fail but be followed by unpleasant results—as ulceration, if used improperly or if the child is suffering from impaired nutrition and a low order of vitality.

Among the large number of erectile tumors that we have treated in this way the results have been almost uniformly successful. In two or three cases that might be given more or less sloughing has occurred, due to strong currents and the bad condition of the patients; but these results should be avoided by increased care in the operation and refusal to operate in low conditions of system. By a somewhat rare coincidence, we have treated within a comparatively short time four widespread nævi involving the nose.

The first case submitted to two operations. The first successfully obliterated the dilated vessels of one-half the nose; but circulation becoming re-established in the other half, a second operation, performed after an interval of several months, resulted in complete recovery. The second case was apparently successful; but as it passed from under our observation, we are uninformed of the ultimate result. The remaining cases recovered promptly after a single operation, and with hardly an appreciable scar.

Wine Marks.—The treatment of wine marks by electrolysis is often successfully attempted, and yet it is a very tedious procedure, especially where the area covered is large. It should be understood also that the most careful treatment will never succeed in removing one of these superficial birth-marks without more or less scarring. The numerous cicatricial contractions necessary to obliterate the dilated and anastomosed vessels are, however, far less objectionable than the unsightly red mark they displace.

The results of electrolysis are certainly superior to those of linear scarification or the so-called tattooing. In the operation for the removal of wine marks less time is consumed in the work if a number of needles are used simultaneously, and for this purpose the electrode, Fig. 187, is

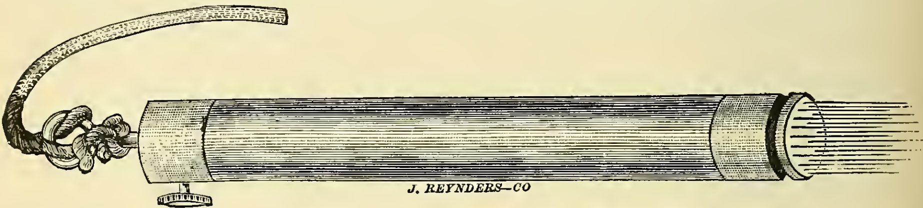
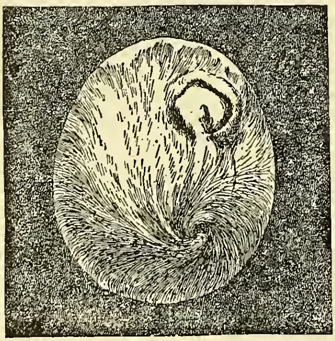


FIG. 187.—Electrode for the Treatment of Superficial Nævi

an excellent device. A dozen or more needles are fitted into a brass disk, the points all being on the same plane. With firm and careful pressure the sharp points are pressed into the disfigured portion to a depth just sufficient to enable the chemic action of the current to reach and destroy the capillary network upon which the disfigurement depends. In some cases



Before Treatment.

After Treatment.

FIGS. 188 and 189.—Angioma of Scalp (Bergonié).

the color returns after a time, which indicates that some larger vessels that supply the superficial network have not been reached. By introducing a single needle to a greater depth it is possible to reach these larger vessels and thus cut off the supply.

Two very interesting cases of angiomata of the scalp and lip are reported by Bergonié,* of Bordeaux, complete cures being obtained by mono- and bipolar electrolysis. In the first case the positive needle (platinum) was plunged into the tumor and a current strength of from 20 to 61 milliamperes passed through. Cure was complete and without pain (Figs. 188 and 189).

* Archives d'Electricité médicale, Bordeaux, January 15th, February 15th, 1893.

G. H. Fox,* of New York, reports a remarkable case somewhat similar, in which the results of treatment were entirely satisfactory.

Goitres.—Goitres are to be treated by ordinary electrolysis with sharp, bayonet-shaped needles, which may be either insulated or non-insulated. Needles that are smoothly insulated can be inserted through the skin of the neck without very much more difficulty than non-insulated needles; but if the insulation be roughly put in, the difficulty in insertion may be very great. An advantage of non-insulated needles is that by the action which takes place in the skin around it, the needle becomes loosened at the negative pole, and so can be pushed in still farther without difficulty. For goitres of all kinds the negative pole is much preferable to the positive pole, just as in cystic and fibroid tumors. There is no danger in inserting a needle even into a small goitre to a considerable depth, say, one or two inches. By great carelessness, it would, we suppose, be possible to wound the carotid artery. We do not usually employ an anæsthetic in the operations on the neck; we find that the ether spray, or local application of a mixture of carbolic acid and ether, equal parts, prevents to a considerable extent the fear of the introduction, which the patient much dreads, and which is really more severe than the pain of the electrolysis after the needles are in position.

In a few cases we have observed that the needles, when inserted in a goitre, cause, by reflex action, pain in the forehead; in other cases nausea and a tendency to faintness are observed. The majority of patients do not bear an operation of more than from five to fifteen minutes, which may be repeated two or three times a week.

This purely electrolytic treatment may be varied by external galvanization.

There is no question that external galvanization with strong currents will cause a considerable reduction of, and sometimes completely dissipate, goitres; and even when this method does not cause any perceptible diminution, it at least relieves the sense of pressure, the heaviness, and the sense of suffocation or of choking that goitres often cause. External electrization alone is not as satisfactory as electrolysis with needles.

The prognosis of goitre, under electric processes, varies with the nature of the tumor. Those which are small and soft may disappear entirely and permanently. Those that are large, provided they are not too hard, may also entirely disappear. The cystic varieties also give a good prognosis. Those that are both very large and very hard may diminish a certain percentage, but they do not entirely disappear. The best method of estimating the results of treatment is to take measurement of the neck. Almost all goitres will go down more or less, and usually at the outset of the treatment. Afterwards they recede more and more slowly; and, even in those cases where the ure is complete, the last quarter will require

* "Diseases of the Skin," vol. iv., section A.

more treatment than the first three-quarters. This is true of all hard growths that are treated by electricity.

Massey * reports the cure of a cystic goitre of large size—35 to 40 milliamperes at first; later, free incision, with application of positive gold-bulb electrode to inner wall of tumor, 50 to 100 milliamperes. Green * reports favorable results in fifty per cent. of his cases.

The use of iodine by cataphoresis may be attempted. McGuire † and others report successful results by this method.

Cystic Tumors.—Benign cystic tumors may be successfully treated by the ordinary method of electrolysis. We have treated many cases, small and large, and with excellent results. The object of the electrolytic procedure in benign cystics is, of course, very different from the object of the

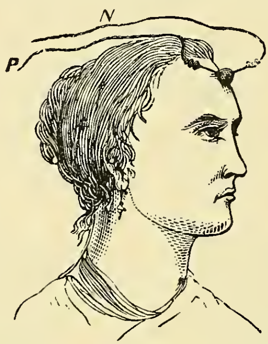


FIG. 190.—Benign Cystic or Erectile Tumor, treated by ordinary electrolysis by insulated needles.

same procedure in nævi. The therapeutic action of the current on cystics is somewhat complex.

1st. The fluid is decomposed. The gaseous products of this decomposition sometimes escape through holes made by the needles.

2d. The walls of the cyst are stimulated so that the fluid is absorbed, and thus the tumor is caused to shrink. This is, in fact, the *rationale* of electrolysis in hydrocele.

3d. Decomposition of the walls of the cysts.

4th. Evacuation of the fluid contents of the cyst without decomposition. This result may follow puncture of any kind, even when no electricity is used. It is more likely to follow electrolysis with the negative needle, for the reason that the needle, when not insulated, acts on the walls of the cyst, and enlarges the opening made by the needle.

In operating on cystic tumors by electrolysis, the best procedure is to insert a needle connected with both poles. The positive needle may be kept fixed, while the negative is worked in various directions, so as to act

* Times and Register, February 24th, 1894.

† Virginia Medical Monthly, August, 1892.

upon all the inner surface of the cyst, and also to enlarge somewhat the hole made by the needle in the walls of the tumor, so as to allow free exit of the fluid or gases.

Large, long, cutting needles are usually preferable when the tumor is large; but for small tumors almost any kind of needle will answer.

Hydatids of the Liver.—Although Durham and Forster * reported many years ago eight cases of hydatid tumors of the liver that were treated with success by electrolysis at Guy's Hospital, very little success, if any, has been reported since.

Fibroids.—Fibroids are usually hard, and therefore slow to decompose under electricity. This is true of all fibroids, wherever situated—in the neck or any portion of the periphery, or in the uterus. Inasmuch as they are not usually malignant, the method of electrolyzing the base, hereafter to be described, are not needed. They are to be treated by ordinary electrolysis, needles connected with both poles being inserted in the tumor. The needles may be insulated or non-insulated, according to the situation of the tumor.

The behavior of fibroids after electrolysis is not generally satisfactory; the amount of decomposition, on account of the density and comparative dryness of the tissue, is but slight; and the subsequent shrinkage and atrophy are not so marked as in goitres or cystic growths.

If a current of sufficient strength be used, the patient being anæsthetized, a suppuration may be excited, and, as a result of the destruction and loss of tissue, the tumor may become somewhat smaller.

Fibroids of the uterus are of sufficient importance to be specially considered. They may be treated electrolytically either through the vagina or through the abdominal walls, according to the position.

The danger of creating peritonitis by thrusting needles through the abdominal walls is but slight; and if the needles are well insulated by rubber, there is really no danger. The insulated part should, of course, go beyond the peritoneum.

Kimball, Cutter, Freeman, Martin, Massey, Gunning, and others since, have reported excellent results from treating fibroids in this way. Further observations in this direction will be found in the chapter devoted to Diseases of Women. While it is rare to see a large and hard fibroid tumor entirely disappear under electrolysis, it yet greatly decreases in size, affording very often complete relief from the various menstrual derangements, and other symptoms that accompany it.

Lipomata (*Fatty Tumors*).—Ordinary surgical treatment with the knife is so successful for fatty tumors that electrolysis would hardly be indicated, even if it could accomplish as much and as easily as the knife. Fatty tumors are, of course, benign, and when operated on do not recur. Fat decomposes slowly and with difficulty, and from our first experiments

* Althaus: Op. cit., p. 645. See also Med. Times and Gaz., November 19th, 1870.

on a number of fatty growths, we were led to believe that secondary absorptive effects would not, as a rule, follow electrolysis. Our later experience, however, in this direction, has been more satisfactory. By using an increased number of needles, more powerful currents, and by prolonging the operations, several of these tumors have been completely dissipated. In every case the operations were rendered entirely painless by the use of the ether spray.

Polypi.—Naso-pharyngeal polypi have been treated by a series of electrolytic operations with success. Von Bruns records a notable case of this kind. As a rule, however, it would be difficult to cure entirely a naso-pharyngeal polypus by electrolysis, and the treatment would be very

FIG. 191.—Removal of Epithelioma of Face by Electrolysis of Base. Both negative and positive needles inserted in the healthy tissue beneath the tumor.

annoying. Polypi in accessible localities are best treated by the galvano-cautery wire-loop.

Epithelioma, Scirrhus, and Other Malignant Growths. — Malignant growths may be defined clinically as those growths which are liable to recur after removal.

Under this head may be classed epithelioma, recurring cysts and fibroids, encephaloids, scirrhus, and so forth. If tumors of this kind are to be treated at all by electricity in the hope of permanent relief, it should be by the method of electrolysis of the base as already described, provided, of course, the tumors are sufficiently accessible.

Pain may, however, be relieved, and in some cases a reduction in size may be gained by the ordinary method of electrolysis, or by simple external galvanization or faradization; and by these methods also the tumor may be arrested in its progress perhaps for a long time.

Of the different forms of malignant growths, the best prognosis for a permanent cure, or for a long deliverance, is in recurring cysts and fibroids; next would come epitheliomata, of which we have successfully treated a number of cases; and last of all scirrhus.

Cancers of the neck of the uterus have been removed by galvano-cautery, but not, so far as we know, by electrolysis of the base.

In one case especially (an epithelial cancer of the rectum and vagina, Figs. 192 and 193) was illustrated most vividly at once the value and limitations of electrolysis in malignant tumors:

1. Its power to control hemorrhage. The growth was so vascular that

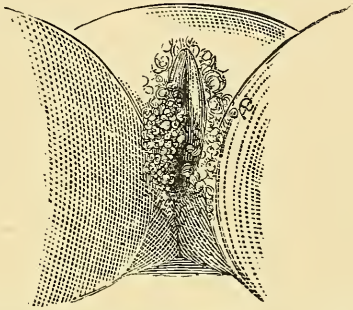


FIG. 192.—Epithelioma of the Vagina and Vulva. Cauliflower appearance.

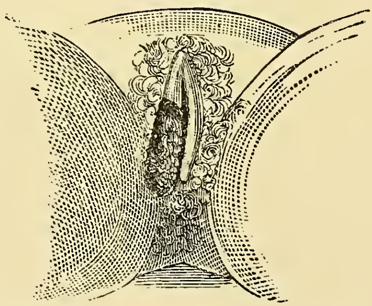


FIG. 193.—Appearance of Granulating Base after Removal of a Portion of the Epithelioma of Vagina and Vulva by Electrolysis.

it bled quite profusely on the slightest touch, and yet under the various and protracted electrolytic treatments to which it was subjected the amount of blood lost was but a trifle.

2. The fact that the electrolytic treatment does not cause shock to the extent that similar destruction of tissue by other methods would be likely to do. Twice, when chloroform was employed as an anæsthetic, the pulse acted badly and compelled us to suspend the operation sooner than we desired; but under etherization the needles were used for half an hour and longer without causing any shock. The stimulus of the current, with the occasional interruptions that are required, seemed, by reflex influence on

the central nervous system, to act as an antidote to shock, as it has appeared to do in other cases.

3. Better healing, and later reappearance of the growth than after the operation by ligature and caustics. When removed by ligature this growth sprang up with great rapidity—in the course of a few days; even before the eyes, as it were, it seemed to enlarge, and to develop an offensive discharge; and the base never began to heal, even on the edges. After thorough electrolysis of the base, this growth not only did not show signs of recurrence for several weeks, but an external ulcer of large size entirely healed. With the internal ulcer on the feebly organized mucous tissues of the vagina we were not so successful.

4. The severe irritative fever that sometimes follows electrolysis. After all the operations, the patient was confined to her bed for several days, and was more or less distressed by inflammation and swelling, not only on the edges of the ulcer, but at some distance down the nates and through the labia. The swelling of the labia was so great that difficulty and pain were experienced in passing water. It should be noted, however, that after the operations with the galvano-cautery and the actual cautery, the irritative fever and surrounding inflammation were much more decided and distressing, and for that reason we returned to electrolysis.

5. The utter inability of even the most thorough and repeated electrolyzations of the base to permanently eradicate the growth in those parts where it was connected with the mucous membrane. Although the base was thoroughly worked up by inserting the needles into the healthy tissue surrounding it so as to completely cut off all communication between the natural and morbid parts, yet the disease extended from the vagina until quite distant parts were attacked and became saturated with cancerous degeneration. The external portion of the growth connected with the perineum and nates was apparently eradicated as thoroughly and as successfully as the cases of epithelioma of the lip previously reported, and the subsequent reappearance of the growth was due to the extension of the disease from the vagina, which part could not be thoroughly affected by electrolysis.

6. The comparative value of electrolysis and galvano-cautery. The healing after electrolysis was incomparably more satisfactory than after the ligation; but in the course of months the growth returned, apparently by extension from the vagina. The irritative fever that followed the electrolytic operations was not observed to any marked degree after the use of the galvano-cautery, and more time elapsed before recurrence.

Take the case all in all, its long standing and wide extent, its excessively rapid growth and still more rapid reappearance after operation by ligature, the frequent repetition of long electrolyzations, and the temporary benefit resulting therefrom, and the opportunity it afforded for comparing the advantages of electrolysis and galvano-cautery, it may probably be regarded as without a precedent in electro-surgery.

Draispul,* of St. Petersburg, reports a remarkable cure of epithelioma of the tongue. The patient was a young man, on whose tongue an ulcer appeared and gradually increased in size. In January, 1892, he came under Draispul's care, the ulcer then being 2.5 centimetres in length and 1 centimetre in breadth, with involvement of cervical glands. A steel needle was connected with the negative pole for ten minutes, and 12 milliamperes were used. Destruction was caused in six sittings. In three months the tongue had entirely healed, with a thin cicatrix, and the glands had disappeared. Microscopic examination showed the growth to be an epithelioma, and eleven months after operation there was no recurrence.

Two General Varieties of Cancer of Breast.—In their relations to elec-

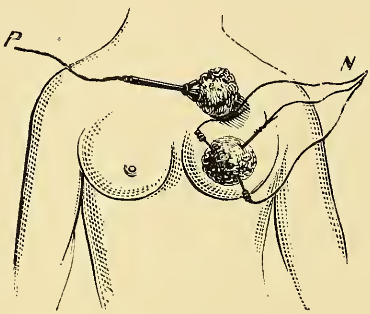


FIG. 194.—Scirrhus of the Breast Treated by Ordinary Electrolysis. Three needles connected with negative pole in body of tumor; connection made by a sponge, the positive pole at the indifferent point on the lupus.

tro-therapeutics there would appear to be two general varieties of tumors of the breast: one variety in which all or nearly all the mamma is involved, and which is very hard, firm, and unyielding, the skin being tense, glossy, and indicating inflammation and induration. The variety is more obstinate and unyielding; the pain may be relieved, but the tumors do not grow smaller under the action of the current; they can be diminished in size or removed only by actual destruction of the tissue.

In the other variety the tumor involves but a limited portion of the breast; the skin is not tense, but is soft and yielding, and of the natural color; the growth is felt as a nodule beneath the skin, and the pain is not usually so severe as in the other variety, and the growth is much slower. This variety is the one that is most disposed to yield to electric treatment. Not only is the pain relieved, but the tumors grow softer and smaller. In other cases their advance is arrested by the treatment, so that they remain stationary for months or years.

Whether what we call, for convenience' sake, and for clinical reasons,

* Journal of Laryngology, London, February, 1894.

only two varieties, are really but different stages of one variety; whether the latter may sometimes come under the head of abscess, or of the atrophying cancer described by Billroth—these questions we resign to the pathologists of the future.

Of the two methods of treating scirrhus, viz., the removal of the growth by the electrolytic process alone, without the use of the knife, or extirpation by the knife, with the subsequent employment of electrolysis for the purpose of destroying the reproductive power of the disease—the latter seems to us worthy of still further trial.

By this method, although two distinct operations are performed, less time is consumed in the operation, and it is possible more effectually, and to a greater depth, to destroy the underlying tissue.

Relief of the Pain of Cancer by Galvanization.—So long as we are able to do so little toward the radical cure of the worst forms of cancer, it can never be amiss to dwell upon any means that will even for a time relieve the awful agony that so frequently attends it.

It is not sufficiently understood what a magic influence an intelligently directed application of the constant current exercises, as a rule, over the throbbing pains of scirrhus, especially of the female breast. Simple external applications with clay electrodes and a current strength of 40 or 50 milliamperes will often act as quickly as the introduction of needles and are far preferable.

J. Inglis Parsons,* acting on the hypothesis "that cancer consists of new cells which have formed during the process of repair or inflammation, and in an active state of proliferation have escaped from the control of the nervous system," used the interrupted voltaic current up to 600 milliamperes, and found the soft varieties were good conductors, while a hard scirrhus had a very high resistance. The severe cancer pain is usually wholly abolished by the first application, if the whole of the growth can be gone over. The number of applications required will depend upon the size of the growth and the amount that can be done at one application. He reported that in one case there were no signs of recurrence at the end of two years, and in two no signs of active growth in seven months and one year. His theory is that the low vitality of the cancer cells is extinguished by the sudden voltaic alternatives, flashed with inconceivable rapidity through the growth.

Hutchinson † stated that he had operated on 16 cases, of which 2 are still living. One was a case of epithelioma of the lower lip, removed fourteen years ago. There has been no return and the patient is in good health. The other was a woman from whom a breast and the two labia majora were removed; after twelve years she is in good health.

Adenitis.—Enlarged glands of the neck or groin may be treated by ex-

* Medical Press and Circular, London, December 24th, 1890.

† Medical News, October 31st, 1891.

ternal faradization with strong currents, interrupted so as to break up the glands, as recommended by Meyer, or by external galvanization, or by electrolysis.

The prognosis is very capricious. In some cases the enlargements diminish quite rapidly and entirely disappear; in other cases they are as obstinate as scirrhus of the breast. In one case referred to us by Dr. C. L. Mitchell, an enlarged parotid gland was treated at first by external faradization and galvanization, with the effect of hastening suppuration. After the tumor was opened the inner portions were treated through the openings by mild electrolysis, and the tumor speedily disappeared.

CHAPTER V.

ANEURISMS AND VARICOSE VEINS.

In the treatment of aneurism the great end sought is coagulation. A knowledge of the differential action of the poles in producing coagulation is essential to an intelligent use of electricity in treating aneurism. Coagulation takes place at both poles of the galvanic current: that at the positive pole being small, black, and hard; and that at the negative being larger, softer, and of a yellowish color.

Aneurisms may be treated, with greater or less success, according to their size and position, the condition of their walls, and general health of the patient, by either of the poles or by both combined.

The best method for the majority of cases, certainly for aneurisms of any considerable size, is to use both poles, and a large number of needles that are insulated, so that the current will not act on the walls of the aneurism. In the treatment of aneurism, especially, careful insulation is needed. The advantage of using both poles is twofold:

First. A double clot is formed, one at the positive and the other at the negative pole. Although the negative clot is soft and yielding, still, in combination with the positive clot, it is of decided service in closing the aneurism; and, so far as we can ascertain, there is no evidence that embolism is ever caused thereby.

Second. The resistance is greatly reduced by placing needles connected with both poles in the sac, so that the electrolytic action is very much more effective than when one pole is placed on the surface of the body. The blood is the portion of the body that best conducts electricity; and when both poles are inside of the sac, and near to each other, as of course they must be, a mild current will cause vigorous electrolysis. On the other hand, if one pole be applied by a wet sponge to some indifferent point on the surface, a strong current is needed to produce a clot, and a long operation; and, unless the sponge on the surface is occasionally moved, it would cause great pain; and if the patient is under an anæsthetic, a blister may be caused. As the negative pole is more painful than the positive, when the positive alone is in the aneurism, the negative on the surface may be very uncomfortable, even with a feeble current. We are aware that tolerably good results have been secured in many cases of aneurism, and especially by the English surgeons, by the positive pole a blone; but we suspectthatetter results might have been obtained if both poles had been inserted into the sac. At all events the use of both poles should be thoroughly tested.

In the electrolytic treatment of aneurism, as in so many other electric applications, it is necessary to have a rheostat, so as gradually to let the current on or off without shock.

Another method of treating aneurism, first suggested by Moore and modified by Stevenson,* consists in passing a large quantity of steel wire into the aneurismal sac, and by this means producing coagulation.

Statistics of Aneurism Treated by Electricity.—The published statistics of aneurism treated by electricity are of little or no value, and for two reasons: 1. They represent experiments made, in a large percentage of the cases, by those who are but little familiar with electro-physics or electro-physiology. Quite frequently the poles have been confounded, so that it is impossible to tell whether the positive or negative is used, and from many of the accounts it is impossible to tell even approximately the strength of current employed.

2. The statistics are derived, in part at least, from cases that are reported too early. The temporary relief that results from the coagulum formed in the aneurism by the chemic action of the current has been interpreted as indicating a perfect recovery.

Some of the cases hastily reported as cured probably died soon after, if not before, the account of their recovery was fully in print.

For these reasons we omit all the statistics that have appeared on this subject; preferring the general average opinion, so far as it can be obtained, of those surgeons and electro-therapeutists who are best qualified to speak on this subject.

Our general conclusion, derived from many experiments on animals, from actual experience, and from a comparison of the various observations that have been made on the subject, is that for those varieties of aneurism—such as the thoracic, abdominal, and so forth—that cannot well be treated by the old methods, and in some cases for those that are accessible to other treatment, galvano-puncture, rightly performed, may be of great service in relieving the accompanying symptoms, in prolonging life, and may now and then achieve a radical cure.

In a case of aneurism of the abdominal aorta that we treated in co-operation with Dr. Keyes, at Charity Hospital, there was a very decided temporary relief of symptoms. The tumor became harder but not smaller, and the bruit, which before the operation was very distinct, became barely perceptible. The needles were introduced on four different occasions at intervals of from one to two weeks; but in spite of the improvement in the condition of the tumor the patient grew weaker and weaker, and died of exhaustion some four months subsequent to the first operation. Post-mortem examination revealed the surprising fact that the patient had three

* Lancet, June 11th, 1887.

aneurisms: one of the arteria innominata, about twice the size of an English walnut; one of the aorta opposite the sixth and seventh dorsal vertebræ, about eleven inches in circumference; and the one operated on, which was found to arise from the anterior wall of the aorta at the origin of the superior mesenteric. This aneurism was about twelve and a half inches in circumference. In all three of the aneurisms organized light-colored clots were found. The one operated on was less solid than the others. There was, indeed, no evidence that the galvano-puncture had produced any permanent clot. It is possible, however, that it caused a temporary clot that was wasted away by the current of blood. There is no question that the tumor became more solid after the operation, and that this solidification was attended with diminution of the nausea and pain.

Luigi Ciniselli * has written a monograph on aneurisms of the thoracic aorta treated by galvano-puncture. He speaks of twenty-three cases. Of these six recovered, sixteen died, and in one case the result is not known. Of the six reported as cured, one relapsed in three months, another in seventeen months, another in four months, but was again operated on, and after eight months there had been no relapse. Of the remaining three cases one had not relapsed up to nine and a half months, another had not relapsed at eight and a half months, and the last remained well at four and a half months.

Eyre has reported a case of aneurism of the left external iliac artery treated by farado-puncture. Symptoms of inflammation appeared, but after seventeen days the tumor was firmer, and evinced less pulsation. The faradic current, however, has nothing to commend it for the treatment of aneurism.

Ciniselli successfully treated an aneurism of the ascending aorta in a patient forty-six years of age by a galvano-puncture. Three needles, connected with a voltaic pile of thirty pairs, were inserted in the third intercostal space where the tumor was prominent and the pulsation strong. The operation lasted forty minutes. After the operation the skin over the tumor was red. For three weeks the patient kept his bed and took digitalis. Forty-three days after the operation he left the hospital. Fifty-eight days after the operation only a slight prominence remained, and no pulsations could be seen. Seventy-eight days after the operation the patient resumed his occupation, which was that of a coachman.

A case of aneurism of the temporal artery, cured by platinum needles, is reported by R. Verhoogen,† of Brussels. Three of these needles were plunged into the sac and connected with the positive pole, the negative be-

* "Sugli aneurismi dell' aorta toracica finora trattati colla elettro-puntura," Miliano, 1870. Quoted in Dr. Keyes's paper on "Practical Electro-Therapeutics," New York Medical Journal, December, 1871.

† Revue internationale de bibliographie, Beyrouth, August 25th, 1894.

ing applied over the sternum. A current of five milliamperes for six sittings in as many weeks sufficed to affect a cure.

Erhoogen,* of Brussels, reports several cases successfully treated by interstitial electrolysis. One was a traumatic aneurism of the temporal artery, about five centimetres in diameter. In seven sittings, at intervals of two days, by means of platinum needles attached to the positive pole, the tumor was reduced without leaving any trace of the treatment.

Gilles,† of Paris, reports two cases of aortic aneurism. In one there was an undoubted arrest of the disease, the restoration of the vitality of the sac, and a survival for six months at least. He thinks that if a second operation had been allowed a cure would have been effected. In the second case, three months' amelioration of symptoms took place, and the treatment was resumed *in extremis*, without result. His conclusion is that we have a right to resort to the operation when all other means have failed to be of value. No details of technique are given.

Varicose Veins.—Varicose veins were treated by galvano-puncture after the manner of aneurisms many years ago.

Bertani and Milani experimented in the treatment of varicose veins by galvano-puncture as far back as 1847. These observers applied a bandage or tourniquet to the limb to diminish the blood supply before operating.

For the treatment of varicose veins the positive pole would possibly be better than the negative or than both together, and for the reasons above given. The space within the enlarged vein is comparatively small, and the small clot made by the positive pole ought to be sufficient to obstruct the flow of blood. The positive clot would have the advantage of firmness, and embolism would be less likely to follow than after the use of the negative pole.

* Journal de Médecine, de Chirurgie, et de Pharmacologie. Brussels. March 18th, 1894.

† Marseilles médical, Marseilles, March 1st, 1893.

CHAPTER VI.

STRICTURES.

Strictures of the Urethra.—The treatment of urethral stricture by electrolysis dates back to 1847, when both Crussel and Wertheimer, as pioneers, published results and advocated the method.

Subsequently, Jaksch and Leroy d'Etiolles studied the subject, and after them, in 1867, Mallez and Tripier,* Campos,† Dutrieux,‡ Althaus,§ and others, contributed to the literature of the subject, and claimed successful results.

In this country the apostle of the electrolytic treatment of urethral stricture is Dr. Robert Newman,‖ who claims to have successfully treated several hundred cases. Simultaneously and subsequently, Frank,¶ Prince,** Hutchinson,†† Butler,‡‡ Meier,§§ and others, have reported cases supporting the claims of Newman.

The leading and distinctive features of his method are these: 1. The use of very mild galvanic currents, three to five milliamperes, and from three to five minutes in duration. Like other observers he uses the negative pole. The instrument should be held loosely against the obstruction, and no pressure should be used, and no force whatever. 2. Long intervals, from two to four weeks, between the applications.

Dr. Newman insists on a careful preliminary diagnosis of the nature

* "De la Guérison durable des Rétrécissements de l'Urèthre, par la Galvano-Caustique Chimique," Paris, 1867. The term "chemical galvano-cautery," used by these authors, is synonymous with electrolysis.

† "De la Galvano-Caustique Chimique, comme moyen du Traitement des Rétrécissements de l'Urèthre," Paris, 1871.

‡ "De la Galvano-Caustique Chimique dans le Traitement des Rétrécissements Organiques de l'Urèthre," Press. Med. Belge, No. 25, 1872.

§ "Heilung der Harnröhren-Stricturen durch die Electrolyse," Goeschen's "Deutsche Klinik," Nos. 34-36.

‖ Archives of Electrology and Neurology, May, 1874. New England Medical Monthly, August, 1885. Journal of the American Medical Association, September, 1887. "Ten Years' Experience in the Treatment of Urethral Stricture by Electrolysis," New York Medical Record, August 12th and 19th, 1882. "A Defence of Electrolysis in Urethral Stricture," Medical Register, Philadelphia, January, 1889.

¶ "Multiple Stricture of the Urethra treated by Electrolysis," New York Medical Record, February, 1874.

** Transactions Illinois State Medical Society, 1873.

†† "Practical Electro-Therapeutics," 1888.

‡‡ American Journal of Electrology and Neurology, October, 1879.

§§ International Journal of Surgery, October, 1888.

and exact seat of the stricture. He operates with bougies provided with metal bulbs of various sizes. Unless the stricture is too firm or fibrous he uses a bougie which is three or four times larger than the stricture. After he has ascertained by measurement the exact locality of the stricture, he pushes a small india-rubber ring over the bougie, at such a dis-

FIG. 195.—Newman's Tunnelled Catheter Electrode (Waite & Bartlett).

tance from the end that when the ring reaches the meatus he will know that the bulb is in contact with the stricture, and then he is assured that the electricity acts only on the stricture.

Dr. Newman regards a patient as cured when a No. 12 English sound can be passed without trouble. He does not claim that all strictures can be treated successfully in this way, but states that some of his cases were bad and complicated.

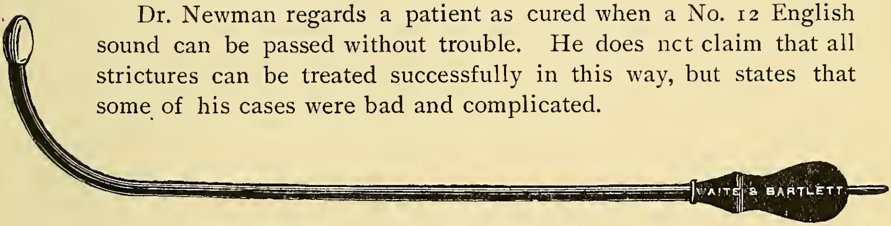


FIG. 196.—Egg-Shaped Urethral Electrode.

Our own experience has not been favorable to the efficacy of electricity in the treatment of urethral stricture. Experiments made in Charity Hospital by Drs. Keyes * and Beard, in 1871, following the old methods of Mallez and Tripier, proved quite unsatisfactory; and in numerous trials since we have been unable to satisfy ourselves of the efficiency of the method. In December, 1894, the following case came to us for the relief of a urethral stricture of long standing. We expressed our doubts as to the probability of effecting a cure by this method, but as the man was eager for the trial, we determined to make still further effort with all possible care and persistency, and called in consultation that eminent authority in genito-urinary surgery, Dr. L. Bolton Bangs, who made all the measurements and assisted at the first six applications.

Mr. X——, aged thirty-five, with a stricture of ten years' standing. Size of stricture at one inch 17 F, and at four inches a second one impassable to a sound No. 11. The first six applications were directed against the first stricture, with an electrode two sizes larger than the stricture itself. The strength of current ranged from five to ten milliamperes, and the length of the applications from two to ten minutes. Some irritation

* See Keyes' article in the New York Medical Journal, December, 1871.

and soreness were occasioned by the use of ten milliamperes, but at the end of a month—the time occupied in giving the six treatments—there was not the slightest evidence that the stricture had been in any way favorably affected. Attention was now directed to the stricture, size 11 at the depth of four inches, and eight additional applications were made between February 1st and March 14th, the electrodes being from one to three sizes larger than the stricture. On no occasion in these last series of treatments did the current strength exceed three milliamperes, and the duration of the treatment ranged from eight to ten minutes.

All this treatment, carried out in the most careful and conscientious manner—on our part with the greatest desire for success, and we are sure also with the same desire on the part of Dr. Bangs—was without result, and on April 13th we sent the patient to Dr. Bangs, who operated by external and internal urethrotomy, with the final result of the easy passage of a No. 26 F sound.

That three milliamperes of current—the strength now generally recommended—applied through a metal bulb, can dissolve an urethral stricture, does not seem a rational supposition. It is certainly opposed to the known principles of electrolytic action. In the year 1888, Dr. E. L. Keyes, whose former unsuccessful attempts in the electrolytic treatment of urethral stricture have been already alluded to, resolved again to test the treatment by the newer method of Dr. Newman and with his aid. A full account of these investigations will be found in an article, "On the Curability of Urethral Strictures by Electricity," read before the annual meeting of the American Association of Genito-Urinary Surgeons, and published in the New York *Medical Journal*, October, 1888.

The accompanying table, compiled by Dr. Keyes, epitomizes the complete history of the eight cases thus treated.

His conclusions are that "electrolysis with a very mild current—I prefer it at less than two milliamperes and a half—does no harm; in fact, does nothing that I can appreciate, and does not interfere with the benefit to be derived from ordinary dilatation. I believe that a strong current is full of danger, both immediately from irritating effect and ultimately from cicatricial effect; and that employment of the negative pole does not prevent this.

"My study of the subject and the experience it has brought me, digested with all the impartiality I possess, lead me to state that the allegation that electricity, however employed, is able to remove organic urethral stricture radically lacks the requirements of demonstration."

The subject has been ably discussed also by Dr. F. Tilden Brown,* of

* An essay read before the Surgical Section of the New York Academy of Medicine upon "The Limitations of Electrolysis as a Therapeutic Agent in Organic and Spasmodic Stricture of the Urethra, with Cases," Journal of Cutaneous and Genito-Urinary Diseases, July, 1888.

Case.	Name.	Age.	Number, size and quality of strictures.	Symptoms.	Former treatment.	No. of sittings.	Sizes of electrodes.	Amount of current and time of employment.	Results during treatment.	Duration of electric treatment.	Duration of entire observation.	Final result when last tested.	No. days between last application of electricity and final testing of urethra.	Result.
										Days	Days		Days.	
I.	A. M.	74	2½ inches, linear, 22 F., films, 5 inches filiform.	Frequent urination; small stream; purulent urine.	Dilatation 35 years ago.	5	16 and 12 F.	4 and 5 milliamperes; 3 and 5 minutes.	Great irritation; failure to pass stricture.	37	228	Recontraction	188	Failure.
II.	L. F.	31	2½ inches, 23 F., films, 5 inches, 19 soft.	Repeated retention.	Relief by sounds.	9	30 and 19 F.	4 and 5 milliamperes; 4 and 25 minutes.	Moderate gleet; comfort in urination as after former use of sounds.	82	225	Recontraction, five sizes.	143	do.
III.	F. S.	33	2 and 3 inches, double linear films, 14 F.	Frequent urination; small stream.	Nothing....	8	10 and 20 F.	4 and 5 milliamperes; 4 and 10 minutes.	Retention from dilatation once.	46	46	Treatment abandoned; dilatation substituted.	Not found later.	do.
IV.	J. H.	35	5 inches, 19 F., linear, soft.	Frequent urination, and retention.	Sounds.....	5	12 and 22 F.	4 and 5 milliamperes; 3 and 17 minutes.	Retention once; pain often.	48	56	do.	do.	do.
V.	M. C.	32	2½ inches, 19 F., triple linear.	Retention	Nothing....	1	17 F.	3 and 4 milliamperes; 8 minutes.	Threatened perineal abscess.	1	24	do.	do.	do.
VI.	W. W. *	40	2½ inches, films, 20 F., 5 inches, soft, 13 F.	Frequent urination; small stream.	Nothing....	3	11 and 26 F.	4 and 5 milliamperes; 1 and 10 minutes.	Vesical irritability and urethral discharge.	21	200	Increase of nine sizes F.	144	Soft, non-fibrous stricture with spasm, overcome; cure permanent.
VII.	M. T.	32	5¾ inches, 8 F., linear films.	Partial retention; small hesitating stream.	Soft bougie, No. 8 F.	1	12 F.	5 milliamperes; 17 minutes.	Retention	1	11	Treatment abandoned to enter hospital.	Not found later.	Failure.
VIII.	J. D.	44	4½ inches, films, double linear, 21 F.	Repeated retention.	Meatotomy, subsequent courses of dilatation.	20	11 and 21 F.	3 milliamperes to an unmeasured quantity; 10 and 20 minutes.	Pain; blood; local distress; stream smaller under treatment.	142	219	Worse by three sizes than before treatment, or by nine sizes if sound is accepted as gauge.	75	do.

* Case of spasm. Cases IV., V., VI., and VII. treated by my assistant, Dr. Fuller. Case VIII. treated for me by Dr. Robert Newman.

New York, who thoroughly digested the literary material up to the date of his paper, and whose conclusions are adverse to the efficacy of the method.

Dr. F. A. Fort,* of Paris, has suggested a new method, which he has termed "linear electrolysis," and from its use he claims good results. His electrolyzer consists of a long, flexible, and slender bougie, in the middle of which a projecting smooth platinum blade (not sharp) is connected with a platinum wire covered with a thin coating of gutta percha. This platinum wire can be put in communication with the continuous current of a battery. The terminal portion of the sound is filiform and serves as a driving bougie, preventing any false passage.

The operation is performed as follows: The electrolyzer being introduced into the canal, the platinum blade is gently pressed against the stricture, and the instrument is put in communication with the negative pole of a continuous-current battery.

This being done, the electrolytic current is allowed to pass until the galvanometer indicates 10 milliamperes (minimum), which is sufficient in nearly all cases. The electrolyzer is slowly driven in against the stricture, and the obstacle, according to Dr. Fort, is generally destroyed in about thirty seconds.

The electrolyzer acts like the urethrotome. It is said to produce a linear division of the stricture, which has the advantage over the urethrotome of not producing a wound by a sharp instrument.

Among others who claimed good results by the method of Fort is Ferris.† His bougie, insulated and set in a platinum disk, is introduced until the disk rests against the stricture. A current of 20 milliamperes is used for four minutes.

Strictures in other parts of the body—of the œsophagus, the rectum, etc.—have all been subjected to electrolytic treatment by enthusiastic workers, and successful results reported. The method has not yet, however, commended itself to the masters in surgery or to the conservative opinion of the profession.

* "Traitement des Rétrécissement par l'Electrolyse linear," Paris, 1894.

† Gaz. Med. di Torino, 1895, Nos. 24 and 26.

CHAPTER VII.

MISCELLANEOUS SURGICAL DISEASES.

Ulcers—Bed-sores.—The earliest attempts to treat ulcers by electricity were made by Crussel in 1847.

The same treatment has been used in syphilitic ulcers by Kyber, of Cronstadt, Rosenberger, of St. Petersburg, and in the majority of their reported cases with success.

Ulcers may be treated with both currents by means of metallic disks or plates covered with soft sponge. Galvanization serves to cure in such cases partly by its electrolytic effects. One electrode may be applied to the ulcer, and the other to the nearest large nerve-branch or plexus, or to the sympathetic or spinal cord. The applications should not be excessively painful. In some cases decided results may follow a single application of electricity to an ulcerated surface. In a case of an ulcer in the leg of a girl eight years of age, one faradization with a current of moderate strength so improved the nutrition of the parts that healing at once commenced, and in a short time entire recovery took place without any further treatment. Ulcers may also be cauterized by the galvano-cautery.

In the treatment of ulcers, and indeed of many conditions, it is a convenience to have one electrode kept in a fixed position without the aid of the physician or of an assistant. For this purpose the adjustable electrodes, provided with a rubber belt which can be passed around the limbs or body, are convenient.

Ulcers may also be treated by prolonged applications with the so-called "body batteries." A disk of zinc is connected by a wire with a disk of silver. Either the zinc or the silver disk may be applied over the ulcer, and the circuit completed by one disk on an indifferent point, or in case there are two ulcers, one may be covered with the silver disk, and the other with the zinc disk. These disks may be kept in position and worn all the time, or only at night.

The results of these prolonged applications are most excellent, especially in bed-sores. We have known them to fail, however, in very bad cases, and notably when great debility existed.

J. Inglis Parsons * cites four cases of rodent ulcer which he successfully treated by electrolysis, preferring it to the knife or caustics, for the reason that it is more speedy, less painful, less liability to hemorrhage,

* London Lancet, November 11th, 1893.

and leaves a less deforming cicatrix. He used two needles with a current strength of 300 milliamperes. Doamer and Marquant * greatly benefited 22 cases of varicose ulcer by the static bath. The ulcer was cleaned by sublimate or other antiseptic solution, covered by a pad of hygroscopic wadding, and the positive pole from a Wimshurst of four plates, giving five sparks per second at eight centimetres, applied for ten minutes. The ulcer was then recovered with an antiseptic pad, the treatment being renewed three times a week. The nutrition of the integuments was stimulated and cicatrization hastened. Hutchinson † has had excellent results in the treatment of rectal ulcers by introducing an electrode of carbon (negative pole) sufficiently large to distend the pouch moderately.

With a strength of 20 milliamperes there comes a sensation of gentle warmth with great comfort, and on the removal of the electrode an inspection showed the mucous membrane pale and well contracted. The ulcers rapidly heal. In a case where there were two ulcers of a centimetre diameter each, both disappeared after four sittings. The rectum must, of course, be thoroughly washed out.

Galvano-ozonization is a term employed to designate the combined action of ozone and the galvanic current in the treatment of ulcers. It is claimed that ozone is generated at the positive pole when the galvanic current is applied to an ulcer, and the ozone thus generated has a curative effect on the ulcer, and aids the other action of the current.

For this reason the positive pole is thought superior to the negative in the galvanic treatment of ulcers, fistulæ, and so forth.

Hemorrhoids.—Piles, external and internal, may be treated by both currents applied internally. Relief of itching, pain, and permanent improvement in the tone of the parts, are sometimes derived from this treatment, but the more effectual way is to use the galvano-cautery or electropuncture with electrolysis. Of these two methods the galvano-cautery is to be preferred as the more effectual and the least painful. By not attempting to do too much, but with light touches frequently repeated, the pile gradually shrivels, and in most instances the patient need not be detained from business a day.

Stumps after amputation that are slow to heal have been successfully treated by electricity, like ordinary ulcers, by Dr. George K. Smith and by Dr. Snively, of Brooklyn.

Gangrene.—Gangrene may be treated electrically in various ways, but especially by electrolysis and galvano-cautery. Alorosoff ‡ gives the histories of two unique cases in which the spread of gangrene of the inferior extremity was arrested by the use of the galvanic current.

Carbuncles and Furuncles.—We demonstrated long ago that faradiza-

* La Médecine moderne, Paris, September 1st, 1894.

† New England Medical Monthly, September, 1893.

‡ La Médecine moderne, Paris, April 7th, 1894.

tion was capable of hastening suppuration, and we have frequently utilized this fact in the treatment, not only of carbuncles and furuncles, but of various other forms of abscesses. Dr. Sass informs us that he has used this treatment in several instances with good effect.

Burns.—Burns in a subacute stage might not unlikely be helped toward recovery by faradization or galvanization.

Synovitis.—In effusions of an acute and very sensitive character, electricity is usually not indicated, but in the subacute and chronic forms it is of great efficacy. The treatment should be directed by the cause and stage of the disease, and by the results of trial in each case.

The treatment of those cases that depend on rheumatism or hysteria should be constitutional as well as local. In some cases general faradization, with special attention to the affected joint, is sufficient; in others the general treatment is sensibly aided by galvanization or faradization of the joint, while in other cases the long percussion static spark appreciably hastens the absorptive process.

Whether the galvanic or faradic current or static electricity is to be preferred for local applications can only be determined by the results of trial. Our custom is to begin with the faradic current or static, and to use it so long as benefit results, and then to change to the galvanic. It should be borne in mind that the greater chemic effects of the galvanic current are in these cases frequently more than counterbalanced by the powerful mechanic action of the faradic and static. Stable increasing currents are to be preferred.

Hydrocele.—Electro-puncture was first tried for hydrocele by Schuster in 1839.

Two needles, one connected with either pole, may be introduced, but the simpler and better way is to use but one needle connected with the negative pole, while the positive is applied externally. The current should then be gradually increased until 20 up to 50 milliamperes are reached, the sensations of the patient being something of a guide as to the amount used. The application should be made for five or ten minutes. One, two, or three applications have been known to effect a cure.

Hydrocele, in short, should be treated electrically like cystic tumors. The great end to be accomplished is not the withdrawing of the fluid, which can be done with the ordinary trocar, but the stimulation of the membrane of the sac, so that absorption shall take place and the fluid not again collect. Many of the failures that have occurred in the treatment of hydrocele have been due to a misapprehension of this fact. In the treatment of hydrocele Gautier * has combined with galvano-puncture the injection and electrolytic decomposition of iodide of potassium, claiming by this method a cure in one sitting.

Sprains (*Strains*).—Sprains of joints of all kinds may be treated by

* Revue Internationale d'Electrothérapie, 1893.

electricity; faradization and galvanization of the affected part with a mild, stable, or gently labile current are indicated. We have in this way treated all stages of sprains—acute, subacute, and chronic—and almost uniformly, thus far, with beneficial or curative results. We, on the whole, prefer the high-tension faradic or static induced current for this purpose.

Sprains in the acute stage, or just passing into the subacute stage, should be treated by very mild currents and by short applications.

In such cases no electrode is so agreeable as the hand of the operator gently passed over the painful part.

We have treated a number of cases of sprains of the wrist in patients who are engaged in manual employments. In such conditions the localized application of the faradic current alone rapidly brings on the recovery.

Sprains of muscles with rupture of fibres, so far as our limited observation goes, do not yield to electric treatment. In the few cases where we have perseveringly used faradization and galvanization we have not been able to see that the slow improvement was in any degree hastened.

Spondylitis (*Pott's Disease*).—Spondylitis is a term that is applied to inflammation of the vertebræ. Among its symptoms are at first changes in shape of the spinal column, obstinate gastralgia, or neuralgic pains in the breast and various parts of the body, and subsequently projection of the diseased vertebræ, deformity of the spine, peculiar attitude and paralysis,* sensitiveness of certain vertebræ, and spontaneous pains in the spine.†

The treatment consists in galvanization of the affected vertebræ, the positive pole being placed over the seat of the disease, and the negative at some point above or below. The results are sometimes beneficial.

Spinal Curvature.—Lateral curvature of the spine, depending on relaxation f the muscles and ligaments, and associated with general debility, is a condition for which general and localized faradization and galvanization of the sympathetic are well indicated, and in which they have wrought most important results. General faradization alone is pretty sure to be of service, both in raising the tone of the system and in permanently relieving the curvature. The electric treatment may be used in connection with mechanic appliances.

Pseudo-Arthrosis (*Ununited Fracture*).—Burman obtained a good result from electric treatment of a transverse portion of the tibia and fibula. After the lapse of a month the bones had not united. A bandage was applied and a current (whether faradic or galvanic is not stated) was applied for half an hour by two needles. Suppuration followed, callus was formed, and entire recovery took place.

* See paper on "Differential Diagnosis of Diseases of the Spine," by Chas. F. Taylor, M.D.

† Benedikt: Op. cit., 312.

Hall also obtained a successful result in a fracture of the thigh by the same treatment. The operation was repeated daily for two weeks.

Moritz Meyer * succeeded in dissipating the hypertrophic callus that followed fracture of the index finger. Operative interference would probably have left the man with a crippled finger and hand. After sixteen *séances* the patient was able to move all three phalanges freely.

We treated a case of ununited fracture of femur at the Long Island College Hospital. Insulated needles were used, and very strong currents. Inflammation was excited, and some improvement was manifest, but the bones were so far apart that it was found necessary for the surgeons to operate in the usual manner.

Hernia.—Delaux reports a case of incarcerated femoral hernia in a woman who refused to submit to an operation. Tumor disappeared after a few applications. The first application was directed to the hernia, and in the other applications one pole was applied to the hernia and the other in the rectum. Before electric treatment was tried the patient was growing worse. Faradization might give tone to the weakened muscles in reducible hernia, and for this purpose we have employed it in a single instance; of the results we have not been informed.

Morbus Coxarius (*Disease of the Hip-joint*).—This condition may be treated electrically, in connection with ordinary mechanic treatment, with the twofold object of hastening the recovery of the lesion and improving the general condition. The methods of treatment that would seem to offer most hope are stable faradization or galvanization of the diseased joints, five, ten, or fifteen minutes daily, alternating with general faradization. This treatment might be used in connection with the ordinary method by extension.

Club-Foot (*Talipes*).—In club-foot it is not unfrequently a great advantage to combine faradization or galvanization of the partially paralyzed muscles with the use of mechanic appliances.

Warts.—Warts, if they were regarded as of sufficient importance, might be removed by electrolysis of the base, or by the galvano-cautery.

Dissolution of Calculi in the Bladder.—The employment of the galvanic current to dissolve calculi was proposed by Bourier in 1801, by Morgiardini and Lando in 1803, and by Gruithuisen in 1813, but was first successfully carried out by Prévost and Dumas in 1823.

The theory of Prévost and Dumas was, that the calculus could be made to crumble by the mechanic effect of the gases generated by the current. In their first experiment they placed a fusible human calculus in water, submitted it to the action of a voltaic pile of 120 elements for twelve hours. Platinum wires were placed against the calculus, on opposite sides. Fine powder soon appeared. At the end of the operation the calculus was found to have lost 12 grains in weight, the original weight hav-

* Berliner klinische Wochenschrift, Berlin, December 2d, 1889.

ing been 92 grains. It was again submitted to the current for sixteen hours, at the end of which time it was reduced to very small fragments that could have easily passed the urethra.

Their second experiment was made on a fusible calculus in the bladder of a living bitch, into which warm water had been injected. The application, which lasted an hour, was repeated twelve times during six days. The calculus had become so friable that the operation was not repeated. Examination of the bitch after death showed evidence that the bladder had been injured by the operation.

In 1835 Bonnet made further experiments along this line, and recently Yvon * has experimented by placing a urinary calculus in an electrode forceps of platinum, immersing it in a solution of sodium sulphate, and allowing the current to pass. If the calculus be of triple phosphates or of earthy carbonates, it will dissolve at the positive pole; if composed of uric acid at the negative. None of these experimenters have, however, attempted the dissolution of calculi in the human bladder.

Extraction of Foreign Bodies by the Electro-Magnet.—Dr. Delore † has suggested the electro-magnet as a means of extracting foreign bodies from the eye, urethra, auditory canal, etc. He states that the magnet has been used for the purpose of extracting pieces of iron and steel from the eye since the days of Fabrice de Hilden. Delore's attention was called to the subject by an attempt which he made to extract a piece of a pin from the external auditory canal. A slender magnet was prepared by M. Fasse, which could be bent at will, but it was found to be not sufficiently powerful. Then M. Fasse suggested the idea of using the electro-magnet for this purpose. With this view he constructed a small electro-magnet composed of a stem of iron, with a bulbous extremity, and covered with several windings of insulated copper wire.

The force that is obtained is in proportion to the strength of the current used to magnetize the iron, the number of spirals, and the diameter of the magnet.

In order to ascertain how much power was necessary to extract needles from the body, a number of experiments were made.

"A needle embedded in the horny substance of the hand to the depth of 3 millimetres requires for its extraction a traction of 89 grams."

"Embedded 16 millimetres deep in the heel of a cadaver requires 400 grams."

"Embedded 4 centimetres deep in the calf of the leg it requires 400 grams."

"If it has perforated the cornea it must have a traction of 39 grams."

The advantage claimed for this method of extracting foreign metallic

* Le Bulletin Médicale, Paris, June 24th, 1894.

† Translated from Lyon Médical in New York Medical Gazette, August 20th, 1870.

bodies is that "it produces no sensation on the surface of the tissues," and also is less liable to injure them than forceps or probes.

The investigations of Dr. T. R. Pooley, of New York, lead him to the following conclusions: 1. That a steel or iron body in the eye may be detected by a suspended magnet when the body lies near its surface. 2. The presence and position of such a foreign body may most surely be found by making it a magnet by induction, and then testing for it by a minute suspended magnet. 3. The intensity of deflection of the needle is proportionate to the depth of the body. 4. Changes of deflection of the needle indicate changes of position in the foreign body.

An interesting case is reported by Hardy.* Forty-eight hours after the injury a small, narrow strip of steel was seen resting on the anterior surface of the lens, so situated as to be covered by the iris unless the pupil was dilated. Only a small part of the lens behind the bit of metal was opaque. Twenty-four hours later the effect of a powerful electro-bar-

FIG. 197.—Electro-Magnet.

magnet outside the eye was tried. When the pole of this magnet had been approached to a distance of four inches from the cornea, the chip was seen suddenly to spring away from the lens to the posterior surface of the cornea. On removal of the magnet the metal fell to the bottom of the anterior chamber, and was then extracted through an incision made as for iridectomy. The lens became afterward opaque throughout, and was then gradually absorbed.

Electro-Magnet.—This instrument (Fig. 197) is for removing bits of iron or steel from the cornea and chambers of the eye. Every surgeon and oculist knows from experience how difficult it is to remove particles of iron or steel filings and turnings from the cornea, even after they have been loosened, and the impossibility of extracting them from the posterior chamber of an eye with ordinary instruments. With the aid of this instrument these operations are easy and simple. To use the magnet the conducting cords are connected with the poles of a battery cell (a cell with zinc-carbon element is the best), and the small stylet brought near or in contact with the particle, which adheres to the magnet and is removed. If the particle of iron is embedded in the cornea, it may be necessary to loosen it and then remove it with the magnet, which can be

* Medical Times and Gazette, April 13th, 1878, p. 401.

done without contact with the eye. If iron or steel has penetrated either chamber, it is then necessary to introduce the small stylet of the magnet, which attracts the particle, which is easily removed. The connections are made so that it can be connected to the cell of any faradic battery, but its magnetic force is greatly increased by adding several cells. This is the more easily done with a combined battery, as one or more cells can be connected at pleasure.

When connected with one cell the magnet will lift 300 grains; by adding six cells, 720 grains.

Girdner's Telephonic Bullet Probe.—The telephonic bullet probe (Fig.

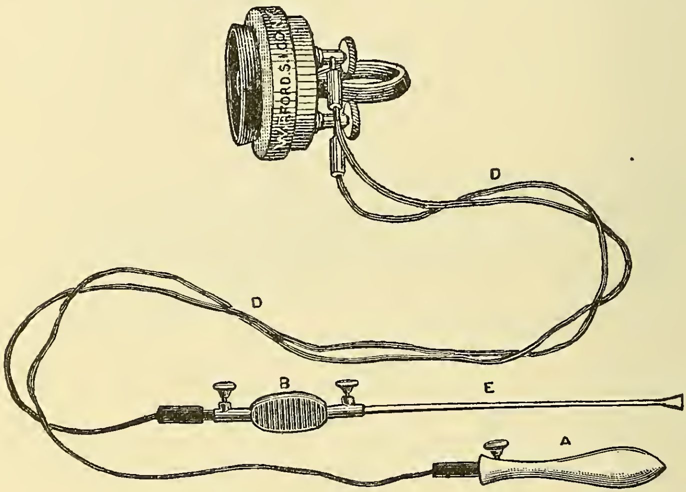


FIG. 198.—Girdner's Telephone Bullet Probe.

198), devised by Dr. John H. Girdner, of this city, is an instrument of precision for locating bullets and other metallic masses lodged in the human body. It is unique in the fact that the electric current which operates it is derived from the body of the patient operated upon; no other battery is used.

A simple battery is made of the patient's body by placing a piece of metal in the buccal cavity, rectum, or vagina, which is different from that to be located. From this piece of metal a conductor leads to a specially constructed telephone receiver; the other conductor from the receiver terminates in a probe of the same metal. When the probe touches the second metal, which is the substance sought for in the wound, the battery is complete and a current passes through the receiver, causing a clicking, grating sound in it.

The cut shows the instrument ready for use, and the following is a description of its construction and *modus operandi:*

To each of the binding posts of the receiver attach one end of each of the conducting wires, *D*, *D*. To the free end of one of these wires attach the bulb *A*, to the free end of the other attach the probe handle *B*, and in the slot of the handle place the probe or needle to be used; be certain all binding posts are tightly screwed and electric contact perfect at each joint, and the instrument is ready for use.

Place the bulb *A* in the patient's mouth, *i.e.*, between the teeth and the cheek, in the buccal cavity; it may also be placed in the rectum or va-

FIG. 199.—Method of Using the Telephone Bullet Probe.

gina, taking care that the lips are kept closed so the moisture in the mouth makes a perfect electric contact between the bulb and cheek. The operator holds the receiver to his ear with one hand, as when listening in a speaking telephone, while with the other hand he passes the probe, *E*, into the wound in search of the bullet (Fig. 199).

Nothing will be heard in the receiver as the probe passes to the various parts of the wound until the bullet is touched; then there will be heard a distinct rasping, grating, or clicking sound in the receiver, and you know certainly that the probe has located the missile.

The slightest touch of the probe with the bullet produces the loudest sound in the receiver; continuous contact of the probe with the bullet produces a continuous current, and hence no sound in the receiver, except a single click at the first contact of the probe with the bullet. The interrupted current, produced by making and breaking the contact when the probe is gently passed over the little irregularities on the surface of the bullet, is what produces the sound in the receiver at the ear. The ear should be trained to use the instrument by experiments as follows: Place the bulb, *A*, in the buccal cavity of an assistant, and after thoroughly wetting one of his hands, place in that hand a piece of lead large enough to enable him to grasp it firmly; then the operator holds the receiver to his ear with the left hand as when listening to conversation in an ordinary telephone; taking the probe in his right hand, he passes it gently over the flesh of the hand and the finger-nails. He will get no response whatever in the receiver until the probe touches the lead in the assistant's hand; then he hears a distinct and characteristic grating or clicking sound. The slightest touch of the probe to the lead produces the characteristic response in the receiver. The hand holding the lead must be kept wet to insure perfect electric contact and to overcome the resistance of the skin to the current, or the instrument will not work.

By experimenting in this way the ear becomes trained so there is no trouble in determining the presence or absence of a bullet in a wound probed.

Both a steel and aluminum bulb, and insulated aluminum probes, and tempered steel needles accompany each instrument.

When the aluminum bulb is used, a probe of similar metal must also be used; but in cases where the course of the bullet has been so tortuous, or the track it made has healed so that it cannot be followed by the probe, the steel needle must be thrust through the tissues in various directions in search for it; in such a case the steel bulb must be used, not the aluminum one.

Hydro-Electrization.—We * have devised a method of applying electricity by means of a continuous stream or jet of water flowing from a metallic tube—or one that has a metallic orifice—connected with one pole, while the body of the patient is in any convenient way connected with the other. A jet or stream of water, so long as it is not broken into spray, will conduct the current from one-eighth of an inch to one or two inches from the orifice, according to the size of the stream, to any part where it may be applied. Contractions of muscles and all the effects of ordinary localized electrization may be thus produced.

This method of electrization is adopted for those localities where, on account of the natural sensitiveness or from the nature of the disease,

* "Further Study of Electro-Anæsthesia," etc. Transactions American Electro-Therapeutic Association, September, 1893.

ordinary electrodes, by their mechanic irritation, cause unbearable pain, or where, for anatomical reasons, they cannot be applied.

For supplying a continuous stream of water we use an ordinary stiff rubber bag, which is filled with water in the usual way, by first compressing the sides and exhausting the air. Connected with this bag we use silver tubes of various shapes and sizes, provided with small thumb-screws for making the connection with the battery, and either insulated or non-insulated, according to the special purpose at hand.

The various douches that are used for the cavities of the body may be utilized for the same purpose, provided the leather tubes are lined with

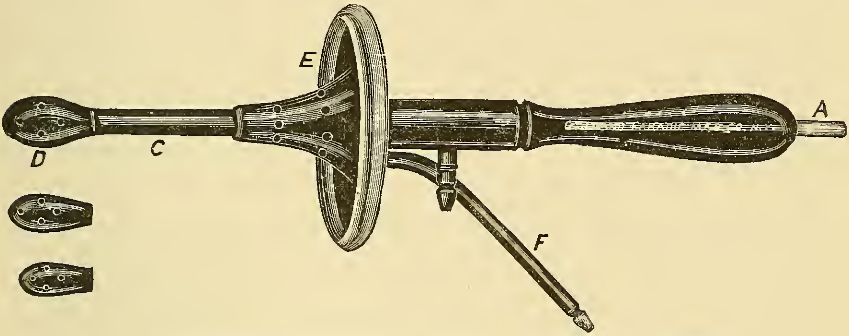


FIG. 200.—Electrode for Vaginal Hydro-Electric Applications (Cleaves.)

spirals of wire, to keep up the connection of the current, or the tubes are composed of metal and insulated.

On this principle, and in order to meet the same therapeutic indications for which ordinary electrization is employed, applications may be made to the external auditory canal, and, in many cases of rupture or ulceration of the membrana tympani, to the middle ear, by a straight, insulated tube, or by the ear douche; to the conjunctiva by a single tube or by the ear douche; to the nasal passages by the nasal douche or metallic posterior nasal syringe; to the pharynx and naso-pharyngeal space by a properly curved tube; to the stomach by the stomach douche, such as has been used by Ploss, of Leipsic, or by the stomach pump; to the bladder by the bladder douche; to the vagina and os by the vaginal douche; and to the cavity of the uterus by the uterine douche; to the cavities of opened abscesses, to stumps that are slow to heal, and finally to all irritable ulcers, wherever situated.

Either the galvanic or the faradic current may be used. Warm water conducts better than cold, and is therefore preferable, except for those cases where the tonic effects of cold are indicated. The conducting power of the water is also increased by the addition of common salt, and various medicinal substances which are ordinarily used for the treatment of the conditions for which hydro-electrization is indicated, and may, therefore, be properly combined with it. Boudet and Larat,* Cleaves,† and Headley ‡ have had extensive and favorable experience in this method of treatment. Fig. 200 is an electrode for vaginal hydro-electric applications devised by Cleaves. In this and in all electrodes for external or internal use the water in every instance becomes the electrode, and by using medicated solutions and platinum wire for the positive pole the contrivance becomes a veritable cataphoric douche. The amount of cataphoric transfer depends upon the strength of the current.

CATAPHORESIS.

The introduction of drugs or medicaments of any kind into the human body has been termed cataphoresis—a property of current purely physical and in no sense electrolytic. In electrolysis either pole is employed for electrolytic effects, but in cataphoresis only the positive pole or anode for cataphoric effects; the process is therefore in every sense an anodal diffusion.

Dr. B. W. Richardson § seems to have been the first to investigate the subject by using a solution of morphine on the anode and producing a local anæsthesia. These were followed by other experiments equally successful, but as a practical measure the method soon fell into disuse, until reintroduced in 1886 by Wagner ‖ and Adamkiewicz.¶

In this country the revival of this interesting method of procedure was due in great measure to the labor of Dr. Frederick Petersen,** who in 1888–89 experimented largely to establish the fact or fallacy of anodal diffusion.

The fact that by means of cataphoresis medicated solutions may be made to penetrate the skin so as to produce absorption and local anæsthesia, has since been confirmed by the experience of many observers. The practical application of anodal diffusion is simplicity itself. Upon the positive electrode is dropped the solution to be absorbed, and the application made directly to the *locus morbi.* Platinum or gold are to be preferred for the positive electrode, as they are absolutely non-oxidizable, but these metals are expensive, and as the necessary strength of current is not great, an ordinary nickel-covered surface will do very well. Block

* Revue d'Electrothérapie, October and November, 1892.

† Journal of the American Medical Association, July 6th and 13th, 1895.

‡ "Hydro-electric Applications."

§ "Voltaic Narcotism," Medical Times and Gazette, February 12th and June 25th, 1859.

‖ Wiener med. Presse, 1886, S. 212.

¶ Neurolog. Centralbl., Pd. v., S. 219–497.

** New York Med. Jour., August 27th, 1889. New York Medical Record, January 31st, 1891.

tin is non-oxidizable by ordinary currents, and used with the smaller sizes of the disc electrode (Figs 158, 159) answers every purpose.

Accuracy of dosage is essential and easily attained. A piece of absorbent cotton or tissue paper is cut so as to fit the metal electrode, and upon this is dropped the solution to be used, and whether it be cocaine, strychnine, atropine, or any one of many drugs that can thus be utilized, accuracy is assured. Pharmacists now prepare medicated cataphoric discs of the various remedies used by this method. The current strength necessary varies from 3 to 20 milliamperes, according to the size of the electrode and the thoroughness of effect desired. Petersen has employed helleborin, strychnine, aconitine, chloroform, and cocaine (ten to twenty per cent), the latter without any constitutional results. In our own experience, however, alarming symptoms in one case supervened during the process of cataphoresis with a much smaller dose of cocaine. Its greatest field of usefulness is in maladies of the skin and mucous membranes, or of immediately subjacent tissues.

In persistent supra-orbital neuralgia cocaine thus used gives relief for from four to ten hours, but does not cure neuralgias of peripheral origin. It was used for diagnostic purposes in a case of idiopathic neuralgia of central origin, and as expected afforded no relief. Chloroform causes dermatitis, and should be used only when counter-irritation is desired in conjunction with transitory anæsthesia. Petersen has employed chloroform cataphoresis in one case of cervical neuralgia with good effect. Helleborin and aconitine have also been used successfully, but the latter, while it gives rise to analgesia, also causes painful smartings and burning, unless combined with a cocaine solution. In its application, it is sometimes useful to prepare the skin a little before treatment by rubbing with ether, to dissolve the oil globules.

There can be no doubt that the effects of the galvanic current upon nutrition are in part due to the cataphoric transfer of molecules of protoplasm and liquid from one cell to another, or from a cell to a capillary vessel in the path of the anodal stream; and since the diffusion takes place more readily and more quickly in direct proportion to the current strength, it behooves us to employ as many milliamperes as feasible in our galvanization of the atrophied and paralyzed extremities of poliomyelitis, chronic neuritis, and peripheral nerve trauma.*

Morton,† by a method which he designates "anæmic cataphoresis," causes the drug to act on that part alone for which it is intended. This he accomplishes by cutting off the blood stream in the part to be treated, by means of an Esmarch bandage, or by a rubber ring, especially for the fingers, after the fashion of an umbrella ring, and then treating by cataphoresis.

* Annual of the Universal Medical Sciences, vol. v., 1892.

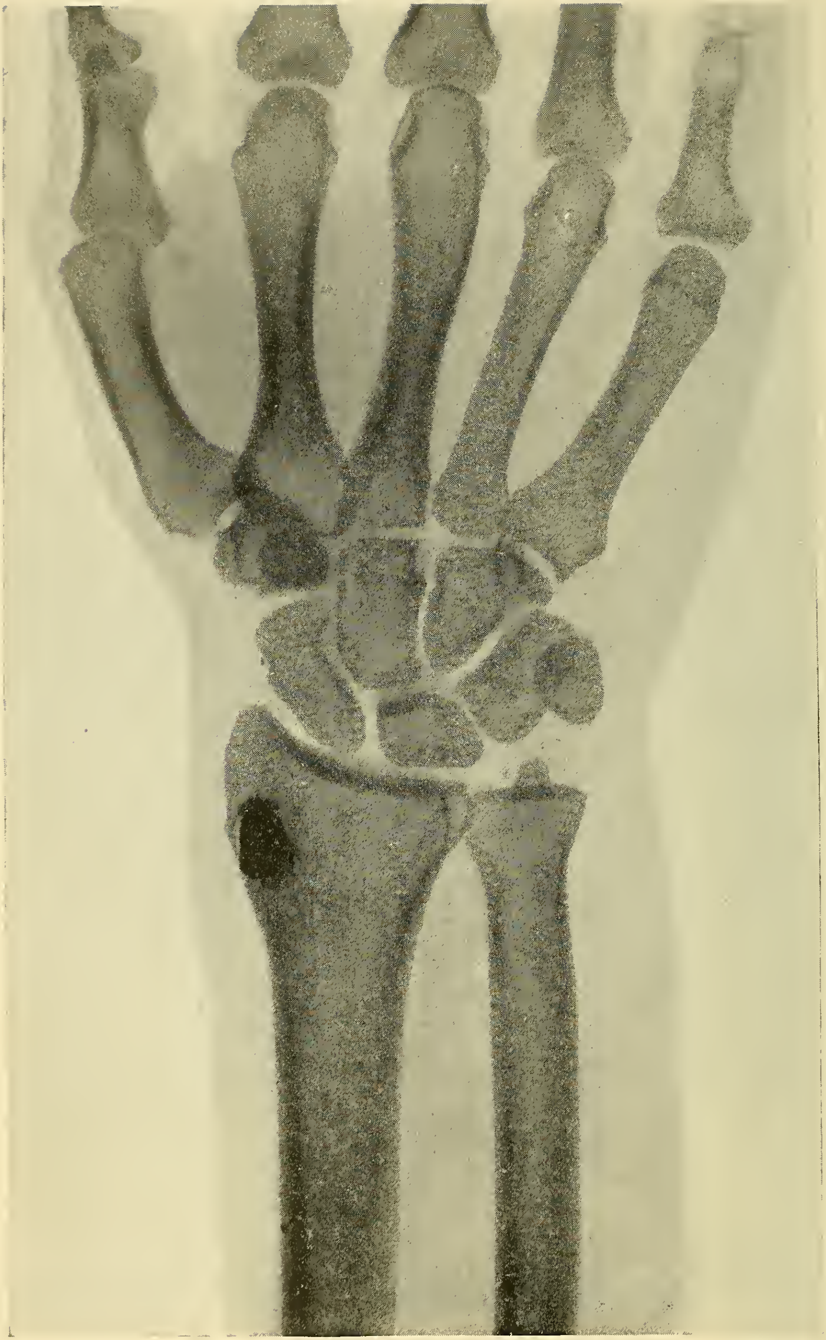
† New York Med. Journal, April 25th, 1892.

By means of the anæmic method of cataphoresis, the medicine employed, or some electrolytic modification of it, comes in direct contact with the affected tissue, and remains for a considerable time in relation with it.

McGuire * reports good results in the use of iodine by cataphoresis in the treatment of ordinary goitre.

The idea of cocaine cataphoresis as a diagnostic method was suggested by Dr. M. A. Starr, for, while it relieves neuralgias of peripheral origin, it has no effect whatever on pains which "owe their origin to lesions far back of the point to which the electrode is applied, as in disease of the Gasserian ganglion, or the idiopathic neuralgias of central origin."

* Therapeutic Gazette, August, 1892.



RADIOGRAPH SHOWING BULLET EMBEDDED IN THE RADIUS.

NEGATIVE BY PROF. A. W. GOODSPEED.

(By courtesy of the Publisher, W. B. Harison, New York.)

CHAPTER VIII.

ROENTGEN PHOTOGRAPHY* IN DIAGNOSIS.

PHOTOGRAPHIC diagnosis by means of the radiant energy of a high-tension electric current operating through a high vacuum tube engages the interest of the world at the moment that this book completes its preparation for the press. Another of the marvels of electricity has been unfolded by Prof. William Conrad Roentgen, of the Physical Institute of the University of Würtzburg. The discovery was accidental, like Daguerre's. Professor Roentgen, long interested in the phenomena of cathode rays, proposed to supplement the researches of Hertz and Lenard by studies of his own. These were begun in the latter part of October, 1895. On the 8th of November he discovered "something new." While working with an induction current of high tension, and a Crookes tube which fortunately possessed an extremely high vacuum and was covered by a black cardboard shield, a piece of barium platinocyanide paper lay on the adjacent bench. Across this paper a peculiar black line appeared. The effect could only be explained by the passage of light, and the shield covering the tube was impervious to any light known. He investigated, assuming that the influence must have come from the tube, since its effect indicated that it could come from nowhere else. He tested it. In a few moments there was no doubt about it: rays were coming from the tube, which had a luminescent effect upon the paper. He tried it successfully at greater and greater distances, even at two metres. It seemed at first a new kind of invisible light. He concluded that the rays were neither light nor electricity, and having discovered their existence and their source, set out to see what they would do.

He found that they possessed a penetrative power unknown before; that they passed with ease through paper, wood, and cloth; that he could see through a book of a thousand pages; that he could photograph brass weights in a closed wooden box, coin in a leather purse, the needle of a compass through its case; and since the rays had this great penetrative power, it "seemed natural that they should penetrate flesh," and this he proved by interposing his own hand. His experiments and surmises he carefully discussed in his now famous report to the Physico-Medical Society of Würtzburg, December, 1895—a report so deliberate, exact, and

* In the preparation of this chapter the valuable assistance of Dr. S. H. Monell is hereby acknowledged.

scientific in character as to leave no room to doubt either its truth or its importance. The studies and steps which led to Roentgen's truly magnificent discovery of rays by which he was able to see through opaque, organic substances and to record images upon sensitized plates began with the immortal Faraday in 1838. They were brought forward in brilliant succession by Maxwell and Hertz, the greatest physicists of our century, and chiefly to the work of these three men, supplemented by that of Philip Lenard, at Bonn, and William Crookes, of London, with his remarkable high-vacuum tubes, we owe the demonstration of the existence of the Roentgen ray, in which more than one eminent scientist is already inclined to see the solution of some of the deepest mysteries of nature. While Lenard had, in 1893, reported upon rays which would penetrate thin films of aluminum, wood, and other substances, and produce photographic effects beyond, it was left to Roentgen to determine that during an electric discharge through a high-vacuum space other rays are set free, of essential differences in kind and of incomparably greater range and power; and so completely has Roentgen's sensational work in a not new field overshadowed all other previous observations that he has by common consent been freely granted the honors of a great and original discovery. On the 4th of January, 1896, he published a shadow picture of the human hand. On January 7th, 1896, a brief cable dispatch of one hundred and fifty words to a New York daily paper first announced in this country that "Professor Roentgen, of Wurtzburg, had discovered a light, which for the purpose of photography would penetrate wood, flesh, and most other organic substances, and that he was already using his discovery to photograph broken limbs and bullets in human bodies."

Instantly the scientific world was eagerly repeating, verifying, and striving to surpass the wonderful experiments of the Bavarian physicist. No other dramatic discovery of this electric age has aroused an interest so universal and commanding. It was reported as "photography," and immediately the photographic world anticipated applications, and sought the development of details which should transform the embyro of Roentgen's revelation into as instantaneous and brilliant a process as time has wrought from the discovery of Daguerre. In electric circles still more active interest was displayed, for the rays were produced by an electric current, and inventors of incandescent light systems, multiphase dynamos, duplex telegraphy, the phonograph, kinetoscope, and telephone, turned their labors to exploring the new field of wonder. But in the medical profession was at once felt the most direct and personal concern. On all sides it was recognized that something had happened which might be destined to enrich medicine and surgery with a more valuable and accurate diagnostic process than was ever hinted at or dreamed of by the great masters of palpation, auscultation, and percussion.

The literature of the subject in the daily, electro-technical, photographic, and medical press assumed enormous proportions within a month from the date of Roentgen's report; his name was in every technical publication in Europe, and he had opened up the most extensive field in scientific speculation. It must be pointed out in passing that partly similar shadow pictures have long since been obtained by ordinary violet light, by arc light, by lightning, by static machine sparks, and even by ordinary sunlight; and with the static spark impressions of coins on glass were made in the last century, but none of these are Roentgen effects proper.

They have been assiduously reported by experimenters and are interesting, but the consideration of them is not relevant to our subject. Actinic luminous, thermal, electric light, and Hertzean rays were all investigated pretty thoroughly before the Roentgen rays were demonstrated at all. Lightning and static-spark effects seem especially to have misled medical but not sufficiently scientific observers into the belief that they were surpassing Roentgen in his own field, a view which Duncan summarily disposes of in an article on "A Lightning Radiograph," published recently.

One point relating to the earlier use of the static machine by Prof. A. E. Dolbear may be best stated in his own words to the writer: "What I did in the way of photography in the dark was in 1892, and consisted in taking a picture of an iron five-pointed star, which was enclosed in a light-proof drawer, by means of the waves from static sparks from a Wimshurst machine, with sixteen-inch plates, giving about four-inch sparks. I alluded to this in the *Cosmopolitan Magazine* for April, 1894. It did not seem to me to be so wonderful in view of Hertz's work, but rather just what might have been expected." Professor Dolbear also refers to the distinction which should be made between photographing in the dark and the photography by Roentgen rays. Most sources of light in common use give off waves competent to do the work which enthusiastic amateurs at first proclaimed as new Roentgen effects.

What are the Roentgen rays? Their as yet unknown nature has given rise to much theoretic discussion and led the discoverer himself to class them provisionally and for the sake of brevity as X rays in his report. He thus states his hypothesis: "A kind of relationship between the new rays and light rays appear to exist; at least the formation of shadows, fluorescence, and the production of chemic action point in this direction. Now, it has been known for a long time that, besides the transverse vibrations which account for the phenomena of light, it is possible that longitudinal vibrations should exist in the ether, and according to the views of some physicists must exist. Should not the new rays be ascribed to longitudinal waves in the ether?"

In his Baltimore lecture of 1884 Lord Kelvin interestingly states: "When we look through the little universe that we know, and think of the transmission of electric force, of magnetic force, and of light, we have no right to assume that there may not be something else that our philosophy does not dream of." The something else to which reference was made was the longitudinal vibration in the ether remarked by Roentgen, and of which Lord Kelvin finally said: "The want of indications of any such actions is sufficient to prove that if there are any in nature they must be exceedingly small, but that there are such waves I believe." In his experiment with the cathode rays, discovered in 1869 by Hittorf, and examined in turn by Goldstein, Varley, Crookes, and Hertz, Lenard replaced a small part of the glass wall of a Crookes tube with a window of aluminum film through which ordinary light could not pass, but through which the cathode rays went out into the surrounding air, penetrating it to a distance of about three inches, and spreading in all directions from the window as a centre. Their presence in the air was shown by a faint glow, by photographic effects, and by fluorescence. Lenard then considered cathode rays as of the same nature with common light rays or waves, but of a much shorter wave length; and although in October, 1895, he published a summary of remarkable investigation into their penetrative properties, he missed the great discovery of the true cause of the phenomena. His position with regard to Roentgen is that of Galvani to Volta. Since the first publication of Roentgen's discovery it has been assumed by most writers on the subject that the new rays bore some relation to the radiant matter of Crookes, which is a phenomenon of the negative electrode. They appear to be originated at the site of the greatest electric activity in the tube. Their real nature is as unknown as the nature of heat, gravity, electricity, mind, and life itself. Apart from the rays themselves, the most curious interest attaches to the prison cell in which they originate. Faraday studied discharges of electricity across a space containing rarefied air within a glass vessel. Geissler made such advances over his predecessors in the construction of apparatus for showing electric discharges through rarefied air, that the name Geissler tube rapidly became familiar in scientific literature. Tubes of this variety—low-vacuum tubes—are usually exhausted to about one-thousandth of an atmosphere, and contain one of the rarefied gases, oxygen, hydrogen, carbonic acid, etc., each exhibiting its peculiar characteristic light when traversed by an interrupted current of high potential. The beautiful and inexplicable luminosity and phenomena observed at the negative bulb of the tube centred the interest in the cathode.

In 1879 William Crookes advanced his theory of the fourth state of matter (the ultragaseous) to account for these cathode rays, and devised new forms of apparatus of such extraordinary interest as now in great measure to supersede the work of Geissler and others. The Crookes high-vacuum tube or bulb is exhausted to about one-millionth of an atmosphere more or less, and furnishes a phenomenon of fluorescence instead of the banded light seen in the Geissler tube. It manifests another singularity.

The electric stream from the negative electrode in the bulb goes out in straight lines to the opposite wall, regardless of the location of the positive electrode, which is usually placed at an indifferent side point. The vacuum in the Crookes tube may also be raised by electric means beyond the capacity of the air-pump, and to so high a degree of rarefaction that no further disruptive discharge will pass through it. Owing to the great resistance between the metallic terminals in the tube and the heavy currents used by some to excite the Roentgen rays, intense heat may be developed in the process. The effectiveness of the tube is thus impaired, and its life may be rapidly destroyed unless certain precautions are observed by the operator.

When Roentgen's discovery was announced there were but few Crookes tubes in this country. Most of those in the shops were unfitted for photographic experiments, and at once a good tube commanded an extravagant price. They vary in shape and size. Some are spherical, some elliptical, some pear-shaped. The latter are preferred. The spheres are about five inches in diameter; the others should be about twelve inches in length and four inches in diameter at the larger end. Every tube has a maximum point of efficiency. It may be over-excited, or over-heated, or too cool, or the vacuum may be too high or too low for the purpose. Effects also vary with the thinness of the wall and distance from the tube to the sensitive plate. Constancy of action is difficult to maintain. Currents from a high-tension source are requisite. Faradic batteries are useless. A powerful static machine with Leyden jars and transformer coils will do fairly good work, but far from the best, for the amperage is not sufficient. Many, including Roentgen himself, have used the Ruhmkorff coil, but the best results cannot be obtained with short exposures by direct connection to an ordinary Ruhmkorff coil even of large size. The make and break of a spring vibrator is least satisfactory to interrupt the current. The direct street current of 110 volts and about 4 amperes volume with a rotary break-wheel, giving a frequency of 110 per second, and raised to a high potential by passing it through a very large induction coil, produces better results than any other method that we have witnessed.

Mr. Swinton, a skilled London operator who has secured excellent plates with exposure time reduced one-half, has excited his tubes from the secondary circuit of a Tesla oil coil, through the primary of which was continually discharged twelve half-gallon Leyden jars, charged by an alternating current of about 20,000 volts pressure, produced by a transformer with a spark gap across its high potential terminal. But in the modest and plainly equipped laboratory in the Pleicher Ring, at Würtzburg, from whence came this new great impetus to scientific research, there were no Tesla coils and no costly and elaborate electric apparatus. There were only the simple Ruhmkorff coil, the Crookes tube, and Roentgen himself. It is the genius of man rather than the perfection of appliances that breaks new ground in the great territory of the unknown.

Methods.—Eder tested extensively the behavior of different sensitive films toward the Roentgen rays, and found that collodion plates gave little or no effect, while bromide of silver, gelatin, iodo-bromide, and chloro-bromide of silver gelatin plates with alkaline development, produced the same results. Plates equally sensitive to ordinary daylight exhibit wide difference of action to the new rays. The shape of the tube and its position relative to the sensitive plate, and the object to be photographed, influence the result. No photographic camera is employed. The photographic plate is secured in an ordinary plate-holder and completely enclosed from the light in a cardboard envelope.

The sensitized surface is turned toward the object to be taken. It is then placed in any convenient situation so that the object may rest directly against the cardboard covering the plate. A fluorescing paper over the plate intensifies the effect and reduces the time of exposure. The vacuum tube is connected by its electrodes to wires leading to the terminals of the electric source, and set up so that the area of greatest efficiency confronts the plate at the distance best suited to the power of the tube. The current is started into action and the exposure time will vary according to the thickness and density of the tissues to be penetrated by the rays. A few minutes suffices for the hand; the entire leg and even trunk of the body have been lately impressed upon the plates in half an hour. It was at first considered that pictures produced in the Roentgen manner were mere shadow silhouettes and not true photographic images. It is, however, certain that the plates we now see which are produced with improved experience in the work are far more than shadows, and exhibit the lights and shades, and contour and detail, which belong to true image photography. Methods, however, are yet in the crudest state. It is seventy years since the French experiments were made which led to the daguerreotype, and the kinetoscope has only recently been born. We are but a few months from the publication of Roentgen's double achievement, and while the world is already seeking improvements upon his process which will take us past the daguerrotype stage into the era of instantaneous and defined photography of living tissues, the maturity of development must wait for the inventive genius of the future.

The first instrument designed to take advantage of the fact noted by Roentgen, that the rays caused fluorescence in certain substances and to make direct visual observations, was a single brass tube, blackened on the inside, to one end of which was secured by non-actinic black photographic paper a circular disk of paper prepared with the double cyanide of platinum and barium. The opposite end of the tube was fitted to the eye so that the light was excluded. This instrument was directed toward the excited vacuum tube so that the acting rays fell upon the fluorescing screen, which then glowed and revealed the shadows of objects between it and the Crookes tube. Salvioni and Magie employed similar instruments, which one called a skiascope and the other a cryptoscope, but which has been superseded by the more effective fluoroscope produced by Mr. Edison, the screen of which is tungstate of calcium crystals. Dr. Emmen has also suggested a photoscope, and probably a number of other instruments will be devised, as seventy-two substances are known to fluoresce under the rays.

The first announcement of Roentgen's work was made in this country without explicit details. Its significance was most quickly and completely grasped by the greater electricians. In general medicine and surgery the matter was viewed with considerable skepticism, especially by those of no electric experience. The early utterances of leading medical journals, even after plates were successfully produced in American laboratories, were ultra-conservative on the subject. Workers in the field of electro-therapy were somewhat better prepared to comprehend the possibilities of the reported discovery and to foresee its practical development.

The results recorded in this country with the Roentgen process have presented as wide variations as the means by which they were secured. Among the thousands of hasty experiments early performed in leading centres of education, many were demonstrated with feeble apparatus and possessed no clinical value. Others, again, followed in the lead of men who had advanced far beyond them, and the work of the rearguard was still reflected with circumstantial detail in hundreds of medical journals and popular magazines after new developments and more wonderful disclosures had made ancient history of commonplace results. All this was taking place in January, February, and March.

It is proper, however, that some record should be made in this volume of these early steps in the application of photography to clinical diagnosis. Spies, of Berlin, was the first after Roentgen to make a picture of a man's hand in which something had caused pain for years. The negative disclosed a small piece of glass, which was immediately extracted. This took place before the 15th of January, 1896. A photograph of his wife's hand, showing the bones, articulations, a ring on the third finger, with faint outlines of the flesh, also early taken by Spies, has been widely exhibited as one of the best delineations of anatomy yet secured. In Berlin not only were new bone fractures immediately "shadowgraphed," but united fractures were pictured through their dressings and splints to verify the results of surgical work. In Vienna embedded bullets were revealed in photographs instead of being probed for. In London a wounded sailor, completely paralyzed, and whose injury was a mystery, was subjected to the same process of examination, and an object was shown to be embedded in his spine, which proved upon extraction to be a small knife-blade. Neusser in Vienna photographed gall stones in the case of one patient.

He announced with confidence that it would shortly be possible to photograph all the organs of the human body. Operations for malformations hitherto obscure, but now clearly revealed by the new art, are already becoming common and are clearly reported from many directions. Czermark, of Graz, has photographed the living skull, and begun the adaption of the new process to brain study. Lannelongue, of Paris, has exhibited to the Academy of Science Roentgen pictures of bones, showing inherited tuberculosis which had not otherwise revealed itself.

Robb reports taking a picture of a human hand for use in a law-suit to prove that the bones of the thumb, which had been crushed and broken in an accident, had been improperly set by the attending physician. Other pictures of similar medico-legal import have been taken. Verdicts have been secured upon the evidence of a negative to the exclusion of the uncertain testimony of conflicting surgical experts. Pupin made two negatives of the hand of a man wounded while bird-hunting. In the first picture, with short exposure, forty shot were counted; in the second, with longer penetration of the tissues and bones, the number was increased to seventy-two. Keen reports Roentgen plates picturing a burned hand with ankylosis of all the fingers at the knuckle-joints and some necrosis of the metacarpal bones; a tubercular elbow-joint; a deformed elbow-joint, the ulna driven into the groove between the two condyles of the humerus and wedging them apart; a resected elbow and shoulder-joint. Adolph and Lenz have successfully photographed connective tissue. Exostoses and bony tumors in various situations have been delineated. A fracture in utero, showing indistinct outlines of the skull, was illustrated in one medical journal.

Wright and Tesla both obtained a shadow picture of the entire skeleton of a rabbit through both the flesh and fur. Small fish, frogs, and mice have been utilized for many experiments. Goodspeed and Cattell published, February 15th, plates as follows:

No. I. Small intestine, containing cent, lead pencil, and gall stone. The latter, being organic matter, is very indistinct.

No. II. Six pins in centre section of liver, 1 centimetre thick.

No. III. Piece of rib covered with cirrhotic liver, 1 centimetre thick.

No. IV. Blade of a penknife covered by 2¾ centimetres of lung tissue.

No. V. Polydactylism with webbed fingers. Osseous union at tops of three phalanges. Extra phalanx at side. Outer and inner carpal bones double, the separation between left bones and the adjacent phalanges being discovered by this process. Living subject, left hand.

No. VI. Ankylosis of terminal phalanges. Enlargement of second phalanx. Arthritis in living subject.

No. VII. Hand of cadaver. Two bullets inserted from palmar surface; piece of glass beneath round bullet. Lateral luxation of terminal phalanges of ring finger. Amputation of middle finger. Crush of central portion of index finger.

Morton also was early in the field and published several interesting plates.

In Montreal and Chicago surgical operations were performed during the first week of February to remove bullets located by Roentgen's pictures. One was found lodged in a man's leg between the tibia and fibula; the other in the hand. On March 12th a scissors blade was similarly located and removed at the Johns Hopkins Hospital, Baltimore. On March 15th a physician in Hartford made photographs of a badly swollen hand, which resulted in finding a piece of glass embedded in a finger. These are but illustrations of many reports. After the middle of March they became too numerous to note. Operators rapidly improved in technique, and the latest work done was usually a great advance upon earlier experiments.

These results were mostly obtained with small currents, small bulbs, short distances, and long exposure. Swinton, of London, and Pupin, of Columbia College, with more efficient apparatus, obtained their best results with greater ease; and these, together with Tesla and Edison, probably surpassed all other experimenters in the magnitude of their achievements. Where others had worked at a distance of a few inches, Tesla, with a powerful disruptive discharge coil and a single electrode bulb, exhausted by his own process to the highest effective degree, easily photographed an object through a plank at a distance of eleven feet in his first experiments, and shortly afterward produced strong shadows at distances of forty feet and more. His work excels in fine details, in the great distances at which his negatives have been made, in the brief time of exposure, and in the discovery that he can partially reflect the rays and intensify their products. In Tesla's pictures of the long structures of birds and small animals, even the cavities of the bones are clearly visible. In the plate of a rabbit not only every detail of the skeleton appears, but likewise a clear outline of the abdominal cavity and the location of the lungs, the fur, and many other features. Clear shadows of the bones of human limbs were obtained by Tesla, and some plates of his have shown such an amount of details as to furnish convincing proof that other great advances in the process will be made. In one of his pictures of the upper portions of his own body, the ribs, shoulder bones, and bones of the upper arm appear clearly. This, one of the most remarkable pictures of early date, was taken through clothing and board cover, at a distance of four feet, prior to March 7th. In an experiment upon the skull, Tesla obtained not only the outline, but the cavity of the eye, the chin and cheek and nasal bones, the lower jaw and connection to the upper one, the vertebral column and articulation with the skull, the flesh, and even the hair; and he believed that he had demonstrated beyond any doubt that small metallic objects, fragments of glass, or bony or calcareous deposits can be infallibly detected in any portion of the body. These results were given to publication March 7th and 14th, followed, on March 30th, with an account of further experiments upon reflection and increase in the efficiency of vacuum tubes.

Fourteen excellent negatives, taken by Magie to April 3d, were among the most satisfactory plates seen by the writer. They exhibit a variety of surgical cases and afford evidence of the practical value of the process. On April 3d and 4th, Professor Pupin succeeded in obtaining clear negatives of the entire body in sections except the pelvic region, the print of the latter having been accidentally ruined by pressure. In taking the trunk a large sensitized plate was strapped upon an assistant's back, and he was seated in a chair facing the Crookes tube. Exposure was one hour and ten minutes. Besides the beautiful delineation of ribs and spine secured, the plate shows a variety of other detail—faint outlines of muscle masses, lights and shades of the cavities, suspender buckles, collar button, the triangles of the neck, prominence of the chin, etc.

It surpasses in magnitude any other negative seen, but was evidently overexposed. The lower extremities taken were those of a case of knee injury sent by the hospital to be photographed. A first plate was made of the injured knee alone. Exposure time, fifty-two minutes. The result was a perfect photograph of the bony structures, surrounded by fainter contour and outlines of the soft parts. The same man was then placed upon the table, and both entire limbs above the ankle exposed to the action of the rays, to obtain a negative in which the enlarged joint could be compared with the normal knee. The tube was kept at a high state of efficiency by a simple device, and the photographic effect was intensified by the usual method of employing an additional fluorescing screen. The result was all that could be desired. The question of photographing through the thickest tissues of the body was settled in the affirmative.

These great plates, twenty-two inches in length, were made with a single pear-shaped tube, 12 by 4 inches in size, fixed 2½ feet above the subject. They probably represent the full efficiency of the present state of this photography. What, then, are the actual results? By these negatives we can detect the presence, shape, outline, and approximate size of bodies the eye cannot see. We can investigate anything of a bony or foreign nature pretty thoroughly, but we can as yet only outline muscle masses. We cannot determine constituents, color, substance, structure, or condition. While the thoracic cavity or gastric wall may be outlined, we cannot observe whether the lungs or the mucous lining of the stomach are normal or inflamed. A pus cavity may be more opaque to the rays than healthy tissue, as pus is a bad conductor of electricity. So, also, may be a cirrhotic liver or an enlarged spine. Certainly the difference between fibrous and bony ankylosis, and fracture and dislocation, will be shown.

But while the present is the elementary stage of development, no one who has seen a really fine plate and compares it with what could have been accomplished in the same field last year, or views it through the remembrance of the early history of sunlight photography, can fail to believe that in due time we shall observe with the eye even the circulation of the blood.

For the present, however, we must pause. No further advance is probable until workers in different fields, in chemicals for sensitizing more delicate or peculiar plates, in the art of developing the images upon the negative, in the means of exciting the rays and rendering them obedient to the laws of light, surmount the difficulties of photographing the secrets of pathology. That the eye of the physician or surgeon, hitherto hopelessly baffled and vainly attempting to diagnosticate by touch and ear the dark mysteries of disease hidden beyond the skin, will eventually be illumined by rays that shall turn the interior darkness into transparent light, is—we may hopefully believe—the promise of the future.

The first successful modification of the action of the rays so that varying densities of tissues lend themselves to the processes of the new art, will bring all morbid growths, all vital organs, all injuries, all deformities, all foreign bodies, even the vermiform appendix, within the visual and photographic field. How much this means to medical and surgical practice, how nearly it may also enable us to study the effects of drugs, to prosecute exact physiologic research, to watch the action of electric currents within the tissue, to observe digestion more freely than was ever possible through St. Martin's celebrated gastric fistula, it is yet impossible to say.

But a new door has been opened wide where none before was known to exist, and through it we may pass into a happier era, when uncertainty and empiricism shall give place to knowledge and definite therapeutics, and medicine shall take its rightful stand among the sciences that are exact.

INDEX.