

# ELECTRICITY IN RELATION TO THE HUMAN BODY.

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THE effect of electricity upon the human body has in recent years become a subject of interest both to the general public and to scientific observers. It is one

which is continually forced upon the attention by the reports in the daily press of accidents due to strokes of lightning, or to contact with electric wires on the streets; by the recent adoption of electricity as a means for executing criminals; and by the extravagant claims of the curative powers of electricity in disease. The actual changes produced in the body by this form of energy, its real effect in the treatment of maladies, together with the aid which electric apparatus can render to physicians, have received careful investigation both by physicists and physiologists. Even the insane are under the mysterious spell, for witchcraft has given place to electricity in the deranged imagination, and it is the voice of the telephone which is now heard by the lunatic who formerly complained of the suggestions of the devil.

The general interest in the subject, therefore, has made it proper to include in the present series of articles one upon the relation of electricity to the human body. And this may be of service not only by summing up what is definitely known as the result of recent scientific investigations, but also by clearing away some of the mysterious and erroneous assertions of those whose interest it has been to deceive the unwary.

In the preceding articles it has been shown that electricity is one of several forms under which energy becomes appreciable and that, like heat, light, or work, it is measurable, and can be produced by or converted into other forms of energy.

There are several manifestations of electrical energy which, though all one

in their nature, must be distinguished from one another in their application to the body.

These are known as frictional or static electricity; current or voltaic electricity, commonly termed Galvanism; and induced electricity, or Faradism. Each of these forms of electrical energy is produced in a different way and has its peculiar effect upon the human organism. Each, therefore, must be considered by itself.

I. *Frictional or static electricity* is the form which is produced by the friction of bodies which are by nature in a different electrical state. If one walks across the room without lifting the feet from the floor, on a dry day, and then touches any metallic object, a spark flies from the finger to the object. Everyone has experimented in lighting the gas in this manner. The effect is due to the fact that frictional electricity has been generated in the body by the rubbing of the feet on the carpet, and that the dry state of the air has prevented its immediate diffusion from the body into the surrounding atmosphere. If the air is damp such diffusion occurs so constantly that no accumulation in the body is possible, and hence on a damp day one cannot get a spark from the finger. The amount of energy in the spark is proportionate to the expenditure of energy in friction, for one will get a larger spark by walking twice across the room than by walking but once, and by rubbing the feet along the carpet instead of stepping lightly. The same effect can be produced by holding one's hands against a revolving glass ball, a method of obtaining frictional electricity pointed out by Hawksbee. Without friction no spark can be obtained, and unless the metal be touched as soon as the friction is made no spark will fly. This shows that ordinarily the body is not in a state of electrification, and that even after being rubbed it soon returns to its natural, indifferent state. The body cannot be kept in a condition

of electrical tension because of the constant diffusion of electricity from it into the air or into the ground. Therefore a permanent storage of electricity in the body is impossible, unless it be carefully insulated. This can only be done by placing a person on a high chair with glass legs, and by having in the room some dishes containing sulphuric acid, which absorbs moisture from the air. Under these conditions, if the body be rubbed vigorously frictional electricity will be produced and stored up, as it cannot escape. But the moment the person rises from the chair, or touches any object in contact with the earth, a spark passes and a slight shock is felt; the tension is relieved and the natural condition is restored immediately. Instead of generating the static electricity on the person by direct friction, it is more convenient to convey it to the body from a frictional machine under the same conditions. This is the common method of applying static electricity, and almost everyone has at some time "taken sparks" from such a machine. While the sparks are passing, various sensations are perceived and effects noticed, but as soon as they have ceased there appear to be no permanent results from the application.

Almost all substances are capable of being put into a state of electrical tension by friction, but when charged they do not always act alike. The experiments described in the first paper of this series have demonstrated that there are two opposite electrical states produced in objects, one termed for convenience positive, the other negative; and it was also shown that an object in one of these states attracts objects in an opposite state and repels those in its own state.

Thus if a pith-ball hanging by a thread and attracted to the glass rod becomes, by contact, charged with positive electricity from the rod, it at once jumps away from the rod, being repelled from it because it is now in the same electrical state as the rod. In the same way the human body, like the pith-ball, can be charged with either positive or negative electricity, and while insulated after being thus charged it will attract things in an opposite state and repel things in a like state.

It is known that when the body is put into an electrical state by friction the hair rises and stands on end. This is because the body and the hair, being in the same electrical state, repel each other, and as the hair is easily moved it rises. The same repulsion is felt by the air about the body, as it becomes charged by diffusion from the skin; if the body is rapidly charged the movement of the air about it may be rapid and be felt as a breeze. This is the same as the electrical breeze which flows from the points of an electrical machine, and which may be made to blow out a candle or turn a little vane. There is no more curative power in the electrical breeze than there is in any draught of air, although the most absurd statements of its effects have been made.

But if the amount of the electric charge is too great to pass off thus easily into the air, an occasional spark will leap from the body to any near object which is not insulated; and, in fact, if the experiment be performed in the dark one may see innumerable little sparks coming from the hair, so that there appears to be an electric halo about the head.

Careful experiments have shown that frictional electricity resides on the surface of the bodies which are charged with it. Thus, if an insulated metal ball be covered with two spherical disks and then charged with electricity, it is found that when the disks are removed they contain all the electricity, and the ball beneath them has none at all. The same is true of the human body, and therefore frictional electricity never penetrates beneath the skin, or produces directly any effects upon the deeper tissues. But it may produce indirect effects. The skin is, of course, very sensitive; and any sudden change of electrical state produced in it, such as the giving of sparks, causes a decided irritation of the surface. This is appreciated by pain at the point from which the spark jumps, and if the spark be large it may burn and raise a little blister. The degree of irritation depends upon the amount of electricity discharged from the point of skin. This may be so great as to burn seriously or even to destroy life, as is seen when one is struck by lightning. Now any irritation upon the

sensitive nerves of the skin, whether by a spark or a sudden blow, sets up a nervous impulse which is carried along the nerves and which causes a number of effects. One of these effects is a sudden movement of the irritated part. One suddenly draws one's hand away from a lighted cigar before one realizes what is touched. Another effect is a reddening of the skin, which is a sort of provision of nature to counteract the effects of any destructive process by increasing the nutrition of the part injured. And the third effect is a conscious perception of a sensation which leads to a train of thought and a state of emotion pleasurable and invigorating, or painful and depressing, as the case may be. The electric breeze is rather pleasant, while sparks are decidedly disagreeable. Hence, even though the direct effect of frictional electricity may be limited to the surface, its indirect effects may be general.

But the same kind of indirect effects may be produced by any mild irritation of the skin. The general effect of static electricity is, therefore, about the same as that of a cold bath, or the muscle-beating of the Swedes, the lomi-lomi of the Sandwich Islanders, the whipping with twigs in a Russian bath, the needle-douche of a Turkish bath, or any other sharp mechanical irritant. All these agents stimulate the circulation, and produce a sense of refreshment which is harmless, and may even be beneficial. There is no mystery about their action, and no very marked curative effect in disease. And there is no special curative power in static electricity which is not common to them all.

There is certainly something rather startling in having sparks applied to or drawn from the body. And this has led to the employment of static electricity to produce marked mental impressions. In the present day, when "mind cure," "Christian science," and "hypnotic suggestion" are discussed on all sides, it needs no argument to prove the interaction of mind and body. Anyone whose toothache has left him at a dentist's door, or whose digestion has been deranged by anxiety, can testify to the fact. And the decided effect of expectant attention in modifying slight

functional disturbances is admitted by everyone, and may be honestly employed in the treatment of disease. It is not surprising that in some maladies an agent so startling and impressive as electrical sparks should be employed to excite the expectation of cure. In hysterical persons, whose ailments are due to a deranged imagination, it often suffices to impress the mind with a positive persuasion that the agent employed is able to cure, and the effect is obtained. How strong the effect of this persuasion may be is witnessed by the almost universal belief during the middle ages of the efficacy of the royal touch in the cure of the "king's evil;" to say nothing of modern miracles. If mystery can be invoked as an aid in the treatment of these imaginary affections the cure is more certain to follow, for the state of expectancy is heightened. It is not surprising, therefore, that the supposed mysterious powers of electrical sparks should have been extolled for the purpose of impressing the mind. Nor is it to be wondered at that without any deception favorable results should have followed the use of static electricity in the hands of physicians who can distinguish the class of cases in which it is likely to be successful. But such results are wholly indirect and due to mental expectation, and should not be ignorantly ascribed to the action of the electricity. And a knowledge of this fact should prevent the abuse of the agent, or any expectation of a curative power in real organic and serious disease—where it cannot be of service.

If the electrical condition of the body remains for a time different from that of the surrounding atmosphere, as it may on a dry day, it is supposed that the state of tension produces an indefinite feeling of discomfort. Such a sensation is often complained of by certain persons just prior to or during a thunder-shower. Some, indeed, are quite prostrated by the occurrence of an electric storm; and the susceptibility of nervous persons to changes in the weather has been ascribed to this cause, though it is often due to a peculiar reaction of the body to dampness rather than to electricity. That persons in a state of illness are more liable to notice such slight



electrical changes in the atmosphere than those in health is a well-known fact, and it is certain that those who suffer from neuralgia are especially sensitive.

II. *Current or voltaic electricity* is different from static electricity in its mode of production and in its effects. It is produced by chemical action in a battery, the work done by the expenditure of energy in the chemical process being partly manifest by the electrical state produced in the elements. There is more or less chemical action going on constantly in the process of nutrition within the body, and therefore the body may be looked upon as a sort of battery for the production of electricity. But the amount thus produced is far too small to be appreciable except by the most delicate tests, and may be disregarded. Whenever, by chemical action, two elements are simultaneously put in a state of electrification it is found that their electric condition is unlike, and if they be joined together there is a tendency for the difference between them to be equalized by means of the passage along the line of connection of a so-called current. Thus if a copper cent be laid on the tongue and a silver quarter placed under the tongue, their edges in contact, a current passes through the tongue, and is perceived as an acid taste. Or if pieces of zinc and of carbon be placed in a tumblerful of dilute sulphuric acid, and their free ends be joined by a wire, it is found that as the acid attacks the zinc a current begins to pass along the wire from the carbon to the zinc. And this current may be so intense, if the acid is strong or the zinc plate is large, as to attract the needle of a compass, or to heat the wire red-hot. It is not necessary to suppose that anything is actually running through the wire—as the term current might imply—but only that a change of state is taking place in the wire which tends to propagate itself in a definite direction from the carbon toward the zinc. Suppose that the wire be cut in two, its ends attached to sponges, and the sponges laid upon the body; then this change of state which takes place in the wire attached to the carbon up to its point of contact with the skin is propagated to the other wire through the

body, and the parts of the body between the two sponges are put in the same state as the wire. It is then said that a current is passing through the body. And just as the wire was heated by the current, so the body may also be heated or otherwise affected if the current is sufficiently strong. Wire is found to assume this change of state easily, and hence it is said to be a good conductor. The body, however, does not, and hence it is said to resist the action of electricity, or to be a bad conductor. How bad a conductor it is may be judged from the fact that under the most favorable circumstances it offers as much resistance to the passage of a current as does three hundred miles of ordinary telegraph-wire.\* It is evident, therefore, that strong currents have to be employed in order to affect the body at all. It is found, however, that the chief resistance to the passage of electricity is offered by the skin,† which is practically a non-conductor, and in order to overcome this it is necessary to keep it warm and moist with a solution of salt, or else to penetrate it with needles and apply the electricity through them. The former of these methods is the one commonly employed, and even then the resistance of the body amounts to about two thousand five hundred ohms. The tissues beneath the skin offer resistance in different degrees, the muscles conducting much more readily than the nerves or the bones. It has been supposed that the electricity in passing through the body is generally diffused through the tissues between the poles. But there is no reason to believe that the human body acts like a homogeneous mass, and it is probable that electric currents uniformly pass along the lines of least resistance. There is every reason to believe, therefore, that when a current is sent through the body it is not uniformly diffused in the tissues, but passes chiefly through the muscles and blood-vessels, which offer the least resistance, and affects to a slighter extent the nerves, and least of

\* The resistance of the body is about two thousand five hundred ohms. A mile of No. 6 iron wire has a resistance of 8.54 ohms.

† The dry skin has a resistance of about one hundred thousand ohms.

all the central nervous system (the brain and spinal cord), which is protected by its bony covering. In order to reach the nerves the current must be specially applied to them. An illustration will make this clear. If from a reservoir several pipes lead out, some of which are full of rubbish and others free and open, it is evident that much more water will flow through the open pipes than through those which are obstructed, and if it is necessary to wash the latter clean some pumping apparatus is to be used, or by closing the other pipes a great pressure of water in the reservoir must be secured. The same thing is true of the passage of electricity through the body. It will pass along the easy ways, and as it is impossible to concentrate accurately its action upon any one set of tissues its effects must always be uncertain.

The amount of electricity sent through the body is measured\* by a galvanometer exactly as currents in wire are measured. But the body is so sensitive that only a few thousandths of an ampère of current can be safely borne. When it is remembered that several hundred ampères pass along the wires of an electric light the danger of receiving a current from them becomes at once evident.

When a voltaic current is passing through the human body three different effects are produced, which are termed respectively catalytic, cataphoric, and electrotonic.

(1) Catalytic effects. A current of voltaic electricity, when sent through a compound substance, decomposes it into its elements, and the action is termed electrolysis or catalysis. Thus a current sent through water splits the water up into hydrogen and oxygen gases, the former of which may be seen coming off from the negative pole in bubbles. Now the human body is a highly complex structure, and, being affected by the electric current exactly as water is affected, it is decomposed by the passage of electricity. With weak currents this process may be but slight, and, since many nutritive processes are attended by such chemical changes, it has been

proven that a mild electric current may aid nutrition by hastening or assisting the chemical changes which are ordinarily going on. This effect of electricity in aiding nutrition has been cleverly shown by Professor Thacher, of Yale College, who applied the current for a week at a time alternately to the two arms of a person suffering from paralysis, and, by measuring the strength of the hands at the end of each week by an instrument which records degrees of power, he found that the power increased more rapidly in the arm to which the electricity had been applied than in the other arm. Thus the gain in size and strength under the use of Galvanism could be shown as follows :

	Galvanized arm.	Untreated arm.
(1) Gain in strength first week (left)...	17°	19°
(2) Gain in strength second week (right)...	15°	10°
(3) Gain in strength third week (left)...	7.4°	0.9°
Total .....	39.4°	29.9°

That is, the galvanized arm made almost double the progress of the other (1 : 1.72). In the same person there was no evidence of gain from the use of faradic electricity or from massage. Such results in aiding nutrition in the body are due to the increased rapidity of chemical changes caused by the catalytic action of electricity.

When, however, the current used is strong, the catalytic action becomes so intense that tissues are destroyed and blisters are raised at the two poles, the one at the negative pole being filled with alkaline and the one at the positive pole with acid fluid. At the same time the tissues about these blisters become affected much as if they had been burned, and the resulting sores are slow to heal and leave deep, permanent scars. It is evident, then, that a strong electric current is very destructive to the body-tissues.

This catalytic action is more intense the more concentrated the current, and therefore in its medical application, small-pointed instruments are used. The action is employed for the decomposition and destruction of new growths, such as tumors, in the body, and in order to enlarge passages or cavities which have become constricted by disease. It is not, however, generally approved, because

\* See "Electricity in the Service of Man," in this Magazine for June, 1899.

its action is not accurately limited and is somewhat uncertain ; its after-effects are unpleasant ; it is extremely painful ; and other methods of surgical procedure are far more precise and successful. This catalytic action has also been employed to remove hairs from the face, a fine needle being inserted at the side of the hair and the current being allowed to destroy the root from which the hair grows. Here it has proved of service, and if carefully employed it leaves no scar.

Since a certain amount of catalytic action is always attendant upon the passage of a current through the body, the use of electricity must always be considered as injurious unless proper precautions are taken to avoid the strong currents which do harm. The reckless handling of electric batteries or the giving of shocks by those who have no purpose excepting to amuse is therefore to be avoided, and the danger of touching a wire used in electric lighting cannot be too strongly urged, as the strong current may disintegrate the body-tissues so rapidly as to destroy life in a few seconds.

(2) The second action of a continuous galvanic current is to move along with it the fluids which lie in its path. This is called its cataphoric action.

If a partition of parchment be fitted in a bowl, and two fluids, one salty, be poured into the compartments, and if the positive pole of a battery be put in the salty fluid and the negative pole in the other, the electric current will carry the salty fluid through the parchment into the other compartment and there the fluid will rise to a higher level. The passage of fluid through the parchment is called osmosis. Such an interchange of fluids through the membranes of the body forms an important part of the process of nutrition and of growth. As electricity will promote osmosis it may increase the nutrition of the parts to which it is applied.

A practical application of the cataphoric action of electricity has recently been made. It is well known that a solution of cocaine applied to many of the tissues makes them insensitive. If a drop be put in the eye the eyeball can be touched without causing a wink.

But cocaine does not affect the surface of the skin, and to render this insensitive the drug must be applied to its under-surface. This is usually done by hypodermic injection. But it has been discovered that an electric current may be used to carry the cocaine through the skin and thus render it insensitive. This is done by applying the cocaine on the positive pole or sponge of the battery and placing this over the part to be rendered anæsthetic. The success of this experiment proves that the galvanic current will carry fluid substances through the skin and into the body. This method, though ingenious, has not been widely employed, because it is more painful and less convenient than the method of hypodermic injection. It is used, however, to quiet the pain of neuralgia. Medicines have been administered in this way in medicated electric baths, but it has been found impossible to regulate the amount given and hence they have fallen into disuse.

(3) The last effect of the voltaic current when passing is to produce under each pole a peculiar molecular state of the tissues termed electrotonus. Inasmuch as the condition at each pole is the opposite of that at the other, there are two kinds of electrotonus, named respectively anelectrotonus (anode, positive pole) and katelectrotonus (kathode, negative pole). The condition at the anode is one of diminished excitability ; that at the kathode is one of increased excitability.

This is the only effect of the electric current which continues after the current ceases to pass, and it may last for a considerable time.

It is a property of living tissue to be excitable to several kinds of stimuli, mechanical, physical, or chemical ; and the excitability varies from time to time. There are times, for example, when one feels irritable and uneasy ; there are other times, as after a good meal, when there is a sense of comfort and repose. What is true of the organism as a whole is true of its constituent parts. And it is one of the powers of electricity to produce in the molecules which make up the various organs changes of irritability in one direction or the other. These changes are greatest in intensity near



the poles and diminish at a distance from them, so that at a point in the body half-way between the poles one effect is neutralized by the other.

It is well proven that this electrotonic effect is quite intense in its results upon the circulation, that it stimulates it, and thereby has a beneficial effect in promoting nutrition. To it are ascribed what are known as the refreshing effects of an application of electricity, the sense of invigoration and comfort that follows the use of a general mild current applied to the entire body when fatigued. Such an effect is quite comparable to the restoring effects of a swim on a hot summer day—and the latter is a less expensive luxury than the former.

To the quieting effect produced by the positive pole of the current is due the relief of pain which follows its application. For it is generally admitted that in many painful affections of a nervous or muscular character the application of a mild continuous voltaic current, with the positive pole upon the painful part, affords prompt relief.

The quieting or exciting effects of electricity would be of much greater advantage in the practical use of the agent, however, if they could be more exactly controlled. It is found, unfortunately, that after a current has passed through the tissues for a time and is then stopped that a condition ensues under the respective poles which is just the reverse of the former state. Thus under the anode, where excitability had been quieted, it is now greatly increased above the normal, a complete reaction having taken place. Hence the anode may fail to relieve pain permanently, though quite effective for a time. And under the kathode, where excitability had been increased, there is at first a quieting effect of very short duration followed by a renewed condition of irritability more intense even than the former state. Hence upon the cessation of passage of a current there remains at both poles a state of excitability. The passage of the current is therefore stimulant in its general and its local effects. It is this stimulant effect which causes the increased circulation already alluded to and the sense of invigoration. It is perceptible in the redness and heat of

the skin under both poles, which remains for some time. And it undoubtedly has a decided and permanent effect upon the elasticity of the walls of the blood-vessels, for if, several hours after an application of electricity, and long after any redness of the skin has passed away, the limb be placed in a warm bath, the redness at once returns in the parts to which the poles have been applied.

It is upon this electrotonic effect upon the tissues that great stress has been laid by those who employ electricity in the treatment of disease. It must be admitted that the effect is produced and that it has some duration. Whether it is of a kind to affect beneficially the various changes in living tissues which occur in the different forms of disease in which it has been employed is an open question, and one upon which the experience of physicians leads them to differ.

*The interrupted voltaic current.* It has just been stated that on stopping the current as it passes an increased state of excitement can be induced in the tissues. If it is desired, then, to produce excitement, the result can be reached by making and breaking the circuit alternately, thus producing an "interrupted current." Or, if a great increase in the irritation is sought, the current can be reversed rapidly, so that a part of the body may be thrown alternately into a state of anelectrotonus and katelectrotonus, each being used to re-enforce the other. Such reversal of the current is termed a "voltaic alternative" and is most intense in its effects, producing more severe shocks to the body than any other procedure.

The excitement produced by an interrupted or an alternative current is employed very extensively in the treatment of paralysis, for by it muscles may be made to contract when they are incapable of voluntary exercise. By the same means impulses may be sent along nerves. It is the sudden change of state in the muscle or nerve caused by the electric shock which throws it into action. The passage of a continuous current does not have the same effect. The interrupted current therefore differs from the continuous current in its action on the various organs. It appears

to have the power of setting them to work, and this effect is of considerable interest.

When an effort is made to close the hand there are several processes gone through with. There is an act of the will directing the character of the movement to be made. This takes place in the brain. It is transmitted along the nerves, from the brain to the muscles, as an impulse. Then there is a contraction of the muscles producing the desired motion. Now, each of these processes can be set going by an electric shock. Thus if the current be applied to that part of the surface of the brain which controls movements of the hand, the motion is made, just as if by act of will. Or if the current be suddenly applied to the nerve in the arm, an impulse is there started which also travels to the muscle and causes the hand to close; or if the current be suddenly applied to the muscles of the hand directly, and not through the nerve, the hand again will close. It is evident, then, that the electricity will produce the same effect as the will-power, no matter whereabouts it is applied in the motor apparatus.

Sensations are also produced by the interrupted current. Tickling or numbness, or heat or pain, is felt at the point of application of the electric poles on the skin of the hand according to the strength of the current. If the current be applied to the nerve in the arm which comes from the skin of the hand, the same sensations are felt in the hand. This is because the hand is joined to the brain by nerve-threads, each part of the hand being joined to its own particular area of the brain, so that one can imagine a little map of the hand projected on the surface of the brain, and all sensations from the hand are perceived in this little area of sensory brain-surface. Now as all sensations reaching that brain-surface have in one's experience come from the hand, when a change of state is produced in that brain-area it is perceived as a sensation and referred to the hand. Hence when an impulse started by electricity in the nerve-threads from the hand arrives at the brain a perception follows, and the sensation is referred to the hand, the

brain having no means of correcting its false impressions except through the aid of other senses. It is because of this fact that people have sensations in amputated limbs long after the amputation, and also for this reason that imaginary pain is really as severe as any other. Electricity, then, sent through a sensory nerve will produce changes of state in the brain which we know as sensations of touch, temperature, or pain.

The same is true of the sensory nerves of sight and hearing and smell and taste. If a current be sent through the eye we see a flash of light. If the experiment be conducted in a dark room it will be found that when the negative pole is applied to the eye and the current is sent, a whitish-yellow light is seen; when the current is stopped a bluish light is seen; when the positive pole is applied to the eye and the current is sent a bluish light is seen; when the current is stopped a whitish-yellow light is seen. Here, then, is an ocular demonstration, not only that electricity affects the optic nerve but also that the poles differ, and that closing the circuit at the positive pole and opening the circuit at the negative pole are similar in their results. If a current be sent through the ear a noise will be heard when the negative pole is put on the ear and the current is closed, also when the positive pole is put on the ear and the current is opened. The acoustic nerve lies so deep that these effects are only obtained by strong currents. When a current is going through the head at any point a decided metallic taste is perceived in the mouth, which is acid at the positive pole and salty at the negative pole. It is said that the olfactory nerve may also be excited by the current, which is then smelt as well as tasted.

All these experiments show that when a shock is given to a sensory nerve an impulse is sent to the brain and there produces a change of state which is perceived as a sensation. The kind of sensation received depends upon the part of the brain affected, since each part has its own function. The functions of the brain may therefore be set in action by electricity reaching it through the nerves.

But the same is true if the electricity



be applied directly to the brain-surface. This direct application can be made in animals, and has been made in man when by a fracture of the skull the brain has been laid bare. Sensations of light, sound, touch, taste, and smell are then perceived, just as when they were excited by its application to the sensory organs or to the nerves from the organs to the brain.

The difference of effect when different parts of the brain are excited affords one of the many proofs that each part of the brain has its own particular work to do. And, as a matter of fact, the earliest experiments which led to the discovery of the localization of brain-functions were made by the application of electricity to the brain. Since this theory is now established and is being practically applied in the detection and localization of brain-diseases and in the successful removal of brain-tumors, the discovery that interrupted electrical currents can set the brain in action has been one of real importance to medical science and has resulted in the saving of human life.

Another important fact in this connection is one of more interest to physicians than to others. It is the fact that in certain diseases the muscles and nerves lose their power of being excited by rapidly interrupted electrical currents such as are produced in a faradic apparatus. This fact is used by physicians as an aid to diagnosis. For it enables a paralysis due to disease in the nerves to be distinguished from paralysis due to disease in the brain. It also serves to expose those whose object it is to deceive. Lazy soldiers in the army, lazy criminals in prisons, and chronic loafers in hospitals who do not want to work, often feign paralysis and plead inability to move, and by this test it is possible to expose the deception.

During the last few years, since electric lighting has been introduced generally, the newspapers have published from time to time accounts of serious accidents due to electric shocks received from the wires. In such cases the wire, which has not been properly insulated, has come in contact with some part of the body and the electric current has passed through the body into the earth.

The currents used in lighting are several hundred times greater than those which can be safely applied to the body. Therefore the shock received is enormous and the sudden change of state in the molecules of the body is so severe as to arrest all vital processes. Very serious results are caused by such shocks. Usually the individual is killed instantly. Sometimes he is only stunned for a time, and then he becomes delirious, and subsequently is found to have paralysis or blindness or epilepsy or even insanity. The most serious forms of nervous disease may be produced by such a sudden change of state in the molecules of the body. And the fact that it is a molecular effect is proven by the lack of any evidence of disease in any of the organs when examined with the microscope after death. The shock seems to suspend all vital activity in the finest cells without lacerating or destroying the different organs.

When the shock is received from a continuous current and this passes for a few moments through the body the tissues may be severely burned, and sometimes hemorrhages are found in the brain and other organs. When it is the alternating current which kills, no such effects are found. But as the shock in the latter case is more severe, death is more common in accidents from alternating currents.

The fact that death may be instantly caused by a severe electric shock has led to the proposition to use electricity in capital punishment, and it is well known that a commission of experts, after careful experiments, have indorsed this method, which has accordingly been adopted in several States. The method employed in the experiments in Mr. Edison's laboratory is to attach the two wires to any part of the animal's body, and then by closing the circuit, either with an ordinary key which may be moved by the hand or by clock-work, or by a hammer, to send the current through the body of the animal. It was found that an alternating current of seven hundred and fifty volts was sufficient to kill a horse weighing 1,230 lbs. instantaneously, death being apparently painless. There can be no question that such a method of execution is more certain,

more sudden, and less offensive to spectators than that of hanging, and therefore it should be universally adopted in criminal execution.

III. The third form under which electricity appears is the *induced* or *magnetic current*, known as *Faradism*. The interruption in a very weak voltaic current is employed to produce a strong induced current in a coil of wire,\* and this induced current is then applied to the body. It does not appear to have any catalytic or cataphoric action. Nor can it be said to have either an anelectrotonic or a katelectrotonic effect, because there is really an alternation of the two as in the voltaic alternative. It has about the same effect upon the body as a voltaic alternating current, and may be employed, as this is, to stimulate the nerves and muscles, to increase the circulation, and possibly to aid nutrition generally.

The induced current can be produced in an apparatus much smaller and more easily portable than any other current. Hence, whenever such effects as it will cause are desired, it is the one employed as a matter of convenience. Its limitations, however, are many, and hence it is less frequently used for medical purposes than the voltaic current. The fact that this current is induced by magnetism should not be taken to imply that by it magnetism can be made to act on the human body. The most careful experiments have shown that the human body is as completely insensitive to magnetism and as wholly unaffected by it as a piece of rubber or of wood. A person may stand between the poles of the strongest magnet, one which might hold up a ton of iron, without the slightest perceptible effect upon any of the bodily functions being produced. Hence all so-called magnetic appliances, brushes or combs, disks, belts, and magnets have absolutely no curative power whatever. A few of these may, by friction, produce static electricity. Some are so constructed of two kinds of metal that on contact with the skin, whose perspiration is acid, a very weak voltaic current is produced, scarcely sufficient, after several hours, to redden the surface.

\* For the means of production of the induced current the reader is referred to the first paper of this series.

The majority of the effects produced by such contrivances are due, like those of the static current, to expectant attention rather than to any action of the agents, which careful investigations have shown to be inert.

The writer once demanded of the agent of a widely advertised "electric belt" some proof that an electric current was produced by it, and suggested that any such current could be detected by means of a galvanometer. This test was objected to, but a little frame holding a dozen pocket-compasses was at once produced, and the power of the belt, which doubtless contained some iron plates, to attract the needles of these compasses was shown as proof of the production of electricity in the belt. Probably many who were ignorant of the difference between electricity and magnetism had been deceived by this so-called test.

Not infrequently there is seen upon the streets an electric machine with ringing bells, and a large index adorned with a sign that "electricity is life." The man in charge invites the passer-by to test his power of taking electricity; and to anyone who stops he relates marvellous stories of the strength displayed by someone who has just gone on, and the wonderful cures which he has made. Such machines are usually faradic batteries, and when one takes hold of the handles the current is strong enough to cause the hands to close forcibly upon them, so that he cannot let go. The current can, of course, be increased up to a painful point. The strength of the current will be determined by the distance to which the outer coil of wire is moved over the inner coil, as in any faradic battery. The index in such a machine has no relation to the strength of current, and is manipulated by a screw in the hands of the exhibitor. It is therefore a fraud, and does not indicate the strength of current used. There is really no limit to the amount of current which one can endure except a limit in the pain which can be borne. Currents received from such a machine or from any battery in this manner can never be specially beneficial, as they only produce a local effect upon the hands and arms, and when these are paralyzed the cur-

rent should be applied to the weak muscles.

While it is evident, from the review of the various effects of the different forms of electricity upon the body, that some of the effects are powerful, it is also evident that they are only beneficial in so far as they increase nutrition. The curative powers of electricity are really very limited, and have often been exaggerated by those to whose interest it is to urge them.

Certain electrical instruments have recently been introduced into medical use which deserve mention. The electric light is so brilliant, and yet can be produced in such a small space without the danger of burning, that it has long been used for illuminating purposes by physicians. It can be introduced into the mouth, or even into the cavities of the body, such as the stomach, enabling the observer to see objects otherwise invisible. Its light can be reflected into the eye or ear or nose very conveniently, since the source of light can be moved.

Another electric instrument is the micro-telephone or phonscope, by which very slight sounds may be detected and magnified. The sounds of breathing and of the heart may thus be made audible; also the sound produced by the contraction of a muscle, and even the sound of the pulse in the wrist may be heard. Such instruments are, however, too delicate and require too nice adjustment to be generally used. A sound, however, having been recorded by the phonograph, may be subsequently made audible to a large number of persons through the graphophone, and this method has been employed by teachers in the instruction of medical students. The phonograph has also been used to record the sounds of coughing. Coughs vary in sound in different diseases, and by producing all the different coughs from the graphophone students may be taught to recognize the differences.

An electric probe or explorer has been invented for the detection of bullets in the body. There are several kinds of these explorers. Some are introduced into a wound like a probe, and consist of

two fine insulated wires bare at the tip and connected with a battery. When the tip comes in contact with the metal bullet the electric current is completed between the wires, and a bell is rung, or index moved, by the battery. Others are constructed on a different principle. The presence of a metallic body near a delicate induced current is enough to change that current slightly by magnetism. An instrument has been constructed which will indicate the presence of a bullet deep in the body when the instrument approaches the right place. Such an instrument was used in the case of President Garfield, but it is said to have misled because of the magnetic effect of the metallic bed-springs upon it, a source of error which had not been considered.

Electrical instruments are also used to detect very slight differences of temperature in the body—a change of one hundredth of a degree Fahrenheit being easily shown by a thermo-electroscope. As such minute changes of temperature are constantly going on in health and are of no importance whatever for diagnostic purposes in disease, this instrument has been discarded, though charlatans have employed it to impress the wondering public by claiming to detect “congestions” which were imperceptible to the thermometer.

Electrical engines or small electro-motors have been employed by surgeons to run small circular saws for cutting bone, and in very delicate operations, such as those about the bones of the face or nose, they have been found very useful. Dentists use these motors in this manner constantly. The little saw can be held like a pen in the fingers and revolved at a high rate of speed by the electric motor, to which it is joined by wires.

The electric cautery is also widely used by surgeons, a delicate wire being heated to a white heat and touched to the spot which is to be burned.

These are some of the practical adaptations made in the construction of medical instruments, and in the future many other useful devices may be expected.