symbols now used to indicate electrical reactions are taken from German words. Charcot in France, Buzzard in England, and the American writers in general, have adopted the German formulæ, so now their use is universal.

The polar method consists in exciting nerve or muscle with one pole, while the other rests on some indifferent spot, as the sternum, as advised by Erb. We are here concerned with the normal or physiological state; hereafter, the pathological conditions will be given. The *normal formulæ* consist in the reactions which ensue on polar stimulation, nerves and muscles being healthy. When the current is closed by applying the cathode to the nerve or muscle to be excited, the symbols are Ka S (Ka, *Kathode;* S, *Schliessung*, closing). When the current is opened or broken by removing or disconnecting the cathode, the symbols are Ka O (*Oeffnung*, opening). Corresponding symbols are used in respect to the anode. Thus, the words anodal closing are An S, and anodal opening, An O. To express muscular contraction the symbol is Z (*Zuckung*); a strong contraction is Z′; for a weak contraction, z, and for a tetanic contraction, Te. In the physiological state, the muscular contractions as induced by the polar method are characteristic, and can be expressed in the symbolic language now employed for the purpose. It is to be observed, in the first place, that the cathode or negative pole has more power to induce muscular action than the anode or positive pole.

The cathode has more effect on closing the circuit; whereas the anode acts more powerfully on opening or breaking the circuit.

The normal formulæ of muscular contractions induced by the polar method may be arranged in three grades:

In the first grade, the weakest current having power to induce any contraction causes it on cathodal closing — whence the formula Ka S Z; and no action takes place from the anode.

In the second or intermediate grade, the strength of current is sufficient to cause strong cathodal closing contraction (Ka S Z′), but no opening contraction; whereas, on anodal opening and closing there are feeble contractions—whence An S z, and An O z.

In the third grade, which is the highest, the current causes on cathodal closing a tetanic contraction, Ka S Te, and a feeble contraction on cathodal opening Ka O z; whereas, there occur decided contractions on anodal opening, An O Z, and on anodal closing, An S Z.

Such are the normal formulæ—such is the normal behavior of muscles; but in disease, as we shall subsequently learn, these formulæ may be much changed, may be even entirely reversed.

Action of Galvanism on Non-striated Muscles.—The physiological differences in the action of voluntary and organic muscular fibers are well exhibited in the results of galvanic stimulation. Instead of a prompt, almost instantaneous muscular contraction, characteristic of the voluntary fiber, a slow vermicular motion is set up in the involuntary, and this movement is propagated from the point of stimulation by a rhythmical action.

Action of the Galvanic Current on the Brain and Spinal Cord.—Until the experiments of Fritsche and Hitzig, Ferrier, Nothnagel, and others, within a few years past, the electric excitability of the brain had not been admitted. It seems now to be established that certain areas of the cortex cerebri are anatomically associated with certain muscular groups. These facts have been ascertained by direct stimulation of these areas of the cortex by galvanic (Fritsche and Hitzig) and faradic (Ferrier) applications. Can the intra-cranial organs be reached through their investing tissues? This is the most important question, and to this, fortunately, we are able to reply in the affirmative. Erb was the first to prove the transmission of a galvanic current through the brain, and now the fact is universally admitted.

On electric stimulation of the cord, results are produced according to the functional powers of the part—pain when the sensory tract is irritated, and muscular movements when the motor is acted on. Hence, the statement of Erb, that these effects may be due to stimulation of the nerve-roots, has a high degree of probability. In the spinal cord, as in the nerves, the inverse or ascending current causes more decided effects.

Electric excitation of that part of the cord between the fifth cervical and tenth dorsal vertebræ causes dilatation of the pupil, whence this region is known as the *cilio-spinal region.* The explanation of this fact is, that in this part of the cord originate filaments of the sympathetic, connected with the cervical ganglia. In the lumbar part of the cord is a similar center, related to the genital apparatus, and hence called the *genito-spinal region.*

Action of the Galvanic and Faradic Currents on the Pneumogastric.—A weak galvanic current sent through the pneumogastric, increases the force and rapidity of the heart's movements; but a strong current arrests the heart in the diastole. After division of the nerve, stimulation of its upper or central portion arrests respiration in the movement of inspiration, but does not influence the heart; but a strong current acting on the lower or distal portion of the nerve stops the heart in diastole. A descending galvanic current, passed through the pneumogastric nerve, suspends the contractions of the stomach. A faradic current directly applied to the pneumogastric, before and after division of the nerve, produces the same results, but more decidedly; applied through the tissues, it has no apparent effect.

Action of Galvanism and Faradism on the Sympathetic System.—Covered by the tissues, the ganglia and fibers of the cervical sympathetic are not acted on by faradic and static electricity, but even a weak galvanic current does affect them. Applied directly to the sym-

pathetic nerves, the effect is tetanizing, and the vessels receiving their innervation from this source contract very strongly. Applied through the tissues, the faradic current has little or no effect.

The kind of action set up by galvanism, and the differences due to the direction in which the current is passing, have been much disputed. The author believes that the experiments and the deductions of Onimus and Legros correctly represent the actual condition. They hold that the direct or descending current, by increasing the normal wave-like or vermicular motion of the muscular layer of the vessels, increases the amount of blood passing through them, and that the inverse or ascending current, by diminishing the vermicular movement, lessens the quantity of blood.

Electro-Diagnosis.—For diagnostic purposes both galvanic and faradic currents are necessary. The polar method has been applied with great success for determining the condition of nerve and muscle. As has been stated, the pole intended for excitation must be placed over the nerve or muscle to be acted on, while the other rests on some indifferent point—for the upper extremity and trunk, the sternum is convenient. If the operator has no assistant, an interrupting handle of the electrode is useful, or an automatic interrupter may be attached to the pole-board, or the interruptions may be effected by simply applying or removing the electrode.

The normal formulæ of nerve and muscle actions have been set forth ; in disease these formulæ are altered—may be, even entirely reversed. It suffices now to state that when a faradic—an induced—current is applied to a muscle, or to the motor nerve supplying it, contraction of the muscle takes place. This is called *faradic excitation*, and it is *direct* when the contraction is caused by application of the electrodes to the muscle itself, and *indirect* when the motor nerve is acted on. When galvanism is used to produce these effects, the term applied is *galvanic excitation*, and this is direct or indirect.

The Diagnosis of Paralysis.—When the paralysis is limited to a group of muscles, to one member, or to one side, the behavior of the paralyzed muscles is compared with the normal. If, however, as is comparatively infrequent, symmetrical muscles are paralyzed, their condition must be contrasted with that of another healthy subject.

The paralysis of muscles may be complete, and yet they react in a normal manner. In other cases, there may be merely quantitative changes ; that is, there is a mere increase or diminution of electric excitability, the polar reactions conforming to the normal, in order. In the third group, the paralyzed muscles are found to be changed, not only quantitatively but qualitatively, in respect to their responses to the electrical excitation. If the muscles respond in a normal manner to both forms of current, it may be concluded that the spinal cord connected by nerve-fibers to the paralyzed part is free from disease.

The changes in respect to the electric excitability, in some cases of paralysis, consist merely in a quantitative increase to both currents : the muscles react to a less strength of current, or more energetically to the same strength. In the latter, while the normal formula is developed by acting on the healthy muscles, on the paralyzed side the reaction is more decided, as indicated by a cathodal closing contraction (Ka S Z) occurring with a very weak current, or Ka S Z becoming, on the application of the same current, a tetanus (Ka S Te) ; also indicated by the early appearance of an anodal opening contraction (An O Z) and the prompt appearance of a cathodal opening contraction (Ka O Z). A hemiplegia of recent occurrence, some cases of spinal paralysis at a very early stage, and very rarely the earliest manifestations of paralysis from nerve-lesions, are illustrative of this state.

The usual condition for which the electrical currents are employed in diagnosis is diminution or loss of electric excitability. Spinal, motor-nerve, and muscular lesions are the most important. "Reactions of degeneration" is the happy term employed by Erb to signify the changes in the electrical reactions. Owing to disease of the cord, or of the motor-nerve trunks, degenerations of tissue ensue, and hence the term. For a very brief period, in some cases, there is an increase of electrical excitability, but a decline then quickly ensues. As regards faradism, the strength of current necessary to cause a contraction of the affected muscles must be constantly increased, and in a short time no strength of current will cause the least movement. The normal formula for the galvanic current is changed, *pari passu*, with the decline of faradic excitability. First, the cathodal closing tetanus ceases (Ka S Te), then anodal closing contraction (An S Z), and finally cathodal closing (Ka S Z) can be excited only by the strongest current. These changes represent a gradually increasing atrophy of the muscles, and the final cessation of the cathodal closing contraction signifies an extreme degree of atrophy, and the disappearance of the muscular elements.

In the condition known as the reactions of degeneration, it is important to distinguish between the reactions of the motor nerve and of the muscles. It has been already pointed out that, whether the motor nerve supplying it, or the muscle itself is acted on, muscular contractions take place. In the changes which ensue in cases of paralysis, the state of the nerve is separable from that of muscle. If the paralysis is due to a lesion of the nerve-trunk—to an inflammation of the nerve, for example—there may be a brief period when, as above stated, the electric excitability is heightened ; but, as the nerve undergoes degenerative atrophy, there ensues a quantitative decline in the response to electrical excitation, to both faradic and galvanic, and by the twelfth day, sometimes earlier, it has usually entirely disappeared, if the lesions have proved destructive and irremediable. On the other hand,

if the injury done is less, and is remediable, the electric excitability is modified only, and not lost. When recovery from the injury, or inflammation of the affected motor nerves takes place, the muscles innervated will respond to the impulses of the will, long before they react to faradic or galvanic stimulation.

When the spinal cord is the seat of disease, as in infantile paralysis, glossolabiolaryngeal paralysis, progressive muscular atrophy, etc., the paralyzed nerves and muscles exhibit most characteristic electrical reactions. As regards the motor nerves, in two or three days, usually, after the paralysis has manifested itself, a regular and steady quantitative decline in excitability to both forms of current takes place, and by the end of the second week, usually, and sometimes by the end of the first week, no strength of current applied to the nerve will cause muscular contractions. At first, cathodal closing ceases, then anodal closing, and finally anodal opening.

The muscular reactions are much changed from the normal. The muscles, in about a week after the paralysis appears, begin to decline in their excitability to the faradic current, and, at the end of two weeks, it is totally lost, and they cease to respond to any strength of application. If regeneration of the diseased nerve-tissue can be effected, restoration of the faradic excitability may be accomplished, but to a less extent than before.

The phenomena connected with the galvanic excitability are very different. For the first week of the paralysis the response of the muscles to the galvanic current declines, as it does to the faradic ; but, after the second week, a remarkable change ensues : then the galvanic excitability begins to increase, and with this there occur qualitative changes in the order and mode of muscular contractions. These consist in a gradual increase of the anodal closing contraction, which soon equals if it does not surpass the cathodal closing, and the cathodal opening contraction declines in the same measure. In other words, an actual reversal takes place of the normal formulæ. If the degenerations continue, and the muscular elements are finally destroyed, the reactions ultimately cease, the last to disappear being a very feeble anodal closing contraction. Such are the *reactions of degeneration.* They occur in cases of spinal paralysis, when the disease in the cord is in direct anatomical association with the paralyzed parts, and in cases of peripheral paralysis when due to injury or disease of nerve-trunks. The so-called infantile paralysis is an illustration of the former, and facial paralysis of the latter. When the disease is situated in the cord above the point from which nerves are given off to the paralyzed members, there is no change in the law of muscular contraction. When, for example, a transverse myelitis exists entirely above the dorso-lumbar enlargement of the cord, the muscles of the lower extremities, although paralyzed, react normally to the faradic and

galvanic currents. Again, in disseminated myelitis there are groups of muscles that react in accordance with the law of normal contraction, and other groups that manifest the reactions of degeneration—the former being in anatomical connection with a healthy part of the cord ; the latter with a diseased area. It follows, therefore, that a proper electrical examination should be made as a means of diagnosis in the diseases of the nerve-centers.

Diagnosis of Sensibility.—By means of the faradic brush, and pointed electrodes closely approximated, the state of sensibility of the skin may be readily marked out. The skin must be carefully dried to prevent diffusion of the current, and then the brush or electrodes conveying the induced current must be carefully passed over the supposed anæsthetic and analgesic area, and the outlines of the affected surface thus ascertained.

The galvanic current by the polar method has been very successfully applied to determine *the state of the auditory nerve.* The pole intended for excitation is introduced through a suitable non-conducting speculum into the ear, previously filled with warm water, and the other pole is placed on the mastoid process, nape of the neck, or any indifferent point. Brenner, of St. Petersburg, who has contributed the most of the exact knowledge now in our possession regarding these auditory reactions, has invented resistance-coils to be utilized in these researches. A strong current, reduced to the necessary point for acting on the auditory nerve by the introduction of sufficient resistances, is passed through the organ, and the resulting sounds, subjective, and audible, of course, only to the patient, indicate the condition of the nerve. These sounds, whistling, singing, roaring, etc., have been reduced to formulated expressions. Although there are differences of opinion in regard to the real value of these auditory reactions, it seems to be now well established that Brenner's method and formulæ are correct in the essential details.

The state of gustatory sensibility is most correctly ascertained by galvanic stimulation of the end-organs of the nerve. For this purpose a pointed electrode, the positive and negative as closely approximated as possible, is carefully passed over the area of distribution of the sense of taste, and its condition noted.

Feigned paralysis may sometimes be detected by faradic stimulation of the muscles, and feigned insensibility by a strong current. Hysterical paralysis is remarkable for the absence of electro-sensibility and the presence of electro-contractility.

THERAPY.—*Manipulation.*—Electrodes for the application of galvanism or faradism are of various shapes and materials. The best, probably, is a disk of carbon covered with wash-leather. A metal disk covered with soft sponge is also much used. The size depends on the purpose to which applied. When large volume and high in-

tensity are the qualities of the current, the electrode should be of large size, of soft sponge, well moistened. For application to small muscles, Duchenne's olive-shaped, curved electrodes are most suitable ; and to individual nerves, metal buttons of various shapes covered with wash-leather. The instrument-makers are now supplied with all forms and kinds of electrodes, so that the operator can always obtain what form of electrode soever he may desire.

When it is intended to act on parts beneath the skin, the electrodes and skin should be well moistened, for the conductivity of the tissues is in direct ratio with the amount of water they contain. On the other hand, if the skin alone is to be acted on, it should be well dried to prevent diffusion of the current. When weak galvanic applications are made, but little tingling is felt by the patient, and hence he may suppose that no curative effect is produced. Under such circumstances, it were better to add a little salt to the water with which the electrodes are moistened.

Electrical applications should always be made to the affected part, and also to those parts in which decided symptoms are felt. The principle of *localized electrization*, as established by Duchenne, was a most important advance. Next, *the polar method* did much to give exactness to methodical applications. When the poles have a fixed position, and are not moved, the application is said to be *stabile*, and, when moved over the part operated on, *labile*. If the direction the galvanic current is taking is parallel to the nerve-current, or from the center toward the periphery, the application is said to be *direct*, or *descending ;* if in the opposite direction, *indirect*, or *ascending*.

General electrization is a term used to indicate the application of either current to the whole surface of the body—one pole placed on the nape of the neck, or to the feet, and the other passed over the whole surface of the body. *Central galvanization* is a term invented by Beard and Rockwell to signify applications to the cervical sympathetic, to the pneumogastric, to the cervical and dorsal parts of the spinal cord, and to the solar plexus. If one pole be placed on the seventh cervical vertebra, and the other in the fossa behind the angle of the jaw ; if the former be kept in this position, and the latter put on the epigastrium ; and, lastly, if the first be moved down the spine to a point opposite the second—there will be brought into the circuit, successively, the ganglia of the cervical sympathetic and their cardiac branches, the pneumogastric, spinal accessory, phrenic, the semilunar ganglion and solar plexus, and the spinal cord.

In what mode soever applied, and at what point, more or less diffusion of the current takes place. Although the current flows from the higher to the lower potential by the most direct route, a greater or less deflection is caused (diffusion) by the resistance encountered on the circuit.

Magneto-Therapy. — The force furnished by the magnet — magnetic polarity—produces distinct effects when applied to plants and to animals, and it has been utilized in the treatment of diseases. It has been shown by Dr. Vansant that the south pole of the magnet applied to a sensitive surface causes pain, while the north pole is free from this action, and indeed relieves the pain caused by the former. Small animals are similarly affected, the south pole causing excitement, and the north pole sedation. Sometimes remarkable curative results are obtained by the application of magnets in *neuralgia* and in *chorea ;* but they often fail utterly. In hysterical affections, *hemi-anæsthesia*, *contractures*, etc., the results are more constant, and, indeed, are often very striking. It is quite impossible to separate the influences due to the imagination from the direct action of the magnet.

The form of magnet used in medical practice is chiefly the horse-shoe, and, to obtain sufficient power, several permanent magnets are clamped together. The magnetic pole with which the effect is intended to be produced may be gently stroked along the course of the nerve in cases of neuralgia, or the magnet may be fastened on the part by suitable straps. The duration of the application will be determined by the effects. In some cases the result is little short of magical ; in others, apparently of the same character, no effect follows.

Galvano-Therapy. — The most important curative results are wrought by galvanism. As a rule, the large, two-fluid elements of the permanent battery are much more effective therapeutically than the small portable combinations. In the Siemens and Halske modification of the Daniell cup, which is so much employed by German electro-therapeutists, and which the author also uses, the resistance within the battery is very great, nearly equal, indeed, to the resistance of the body. Hence, the current is smooth and uniform, and hence, also, the good results obtained from it.

Allbutt made a number of experimental observations at the West Riding Lunatic Asylum on the therapeutical effects of electricity (galvanism) in *psychical disorders*, and he sums up his results as follows : Marked improvement in *acute primary dementia ;* distinct improvement in *mania*, *atonic melancholia*, and perhaps recent *secondary dementia ;* no change observed in *chronic dementia* and some cases of melancholia, and an unfavorable effect in *hypochondriacal melancholia*, and perhaps *brain-wasting*. In the cases reported by Allbutt, the current was sent through the head and through the cervical sympathetics. Benedict (page 222) reports three cases of mental disorder improved by galvanism.

I have observed excellent results in the mental and other symptoms—*confusion of mind*, *impaired memory*, *hypochondriasis*, *vertigo*, etc.—which result from imperfect nutrition of the brain, caused by atheromatous degeneration of the cerebral vessels. My method of