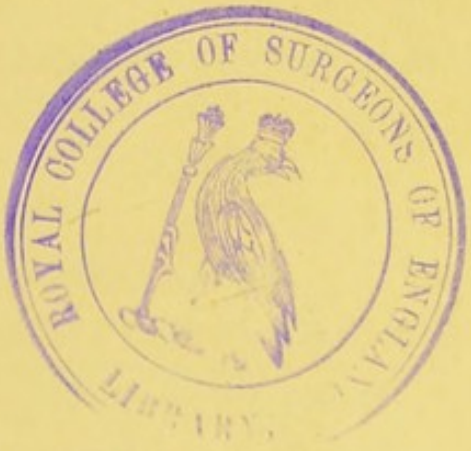
Electricity and its manner of working in the treatment of disease : a thesis for the M.D. degree of the University of Cambridge / by W.E. Steavenson ; to which is appended an inaugural medical dissertation on electricity for the degree of Doctor of Medicine of the University of Edinburgh written in Latin by Robert Steavenson, 1778 ; with a translation by Frederick Robert Steavenson.

With Dr. Steavenson's compts

ELECTRICITY

BY

W. E. STEAVENSON, M.D.



ELECTRICITY

AND ITS MANNER OF WORKING IN THE TREATMENT OF DISEASE

A THESIS

FOR THE

M.D. DEGREE OF THE UNIVERSITY OF CAMBRIDGE

BY

W. E. STEAVENSON, M.D., M.R.C.P.
M.R.C.S. Eng., L.S.A.
HOLDER OF THE CAMBRIDGE CERTIFICATE IN SANITARY SCIENCE
NATURAL SCIENCE PRIZEMAN OF DOWNING COLLEGE, CAMBRIDGE
CASUALTY PHYSICIAN AND ELECTRICIAN TO ST BARTHOLOMEW'S HOSPITAL, LONDON; AND PHYSICIAN TO THE ALEXANDRA HOSPITAL FOR CHILDREN; AND FOR WOMEN AND CHILDREN TO THE ST GEORGE'S AND ST JAMES'S DISPENSARY
FORMERLY
HOUSE SURGEON AND HOUSE PHYSICIAN TO ST BARTHOLOMEW'S HOSPITAL; AND TO THE HOSPITAL FOR SICK CHILDREN, GREAT ORMOND STREET

1884

TO WHICH IS APPENDED

AN INAUGURAL MEDICAL DISSERTATION ON

ELECTRICITY

FOR THE

DEGREE OF DOCTOR OF MEDICINE OF THE UNIVERSITY OF EDINBURGH

WRITTEN IN LATIN BY

DR ROBERT STEAVENSON

1778

WITH A TRANSLATION BY THE

REV. FREDERICK ROBERT STEAVENSON, M.A.

OF COLESBORNE, GLOUCESTERSHIRE
LATE CLASSICAL SCHOLAR OF EMMANUEL COLLEGE, CAMBRIDGE

LONDON
J. & A. CHURCHILL
11, NEW BURLINGTON STREET
1884

AS THIS VOLUME

IS SOMEWHAT OF A FAMILY PRODUCTION

I HAVE DEDICATED IT

TO MY BROTHER

JOSEPH LEWIS STEAVENSON

OF SHANTOCK HALL, BOVINGDON, HERTS.
CAPTAIN 1ST BATTALION ROYAL IRISH FUSILIERS
(LATE 87TH REGIMENT)

AND TO THE

REV. ROBERT STEAVENSON

OF NEWTON HALL, STOCKSFIELD-ON-TYNE
GRANDSON OF THE LATE DR ROBERT STEAVENSON

W. E. STEAVENSON.

ELECTRICITY

AND ITS

MANNER OF WORKING IN THE TREATMENT OF DISEASE

I HAVE taken as a model for this thesis one written more than a hundred years ago by an ancestor for the M.D. degree of the University of Edinburgh.* I have adopted the same title, and will endeavour to show the advance made in the application of electricity to medicine during the past century. The thesis to which I refer was one of the earliest dissertations upon medical electricity written by an Englishman, and at the time was a work of much repute. The whole science of electricity in its application to medicine has now changed. At the time when Dr Robert Steavenson wrote only statical electricity was

* 'Dissertatio Medica Inauguralis, de Electricitate et Operatione ejus in Morbis Curandis.' Robertus Steavenson, A.M. Britannus; Edinburgi, MDCCLXXVIII.

known. Eight years later Galvani made his wonderful discovery of the presence or production of electric currents in the nerves of a frog,* and five years later still† made his discovery known. This gave rise to the origin of galvanism. Forty years‡ after this our great philosopher Faraday discovered the secret of induction, which gave rise to what is now called faradism. These two forms of electricity are those which are now most frequently employed in the treatment of disease.

The little advance we have made in the application of electricity to medicine is due to a variety of causes, but chiefly to the expense and cumbersomeness of the necessary apparatus, the difficulties connected with its administration, and the disrepute into which the science has fallen by the use made of it by unscrupulous and ignorant men. More quackery has gone on under the names of electricity, odic force, animal magnetism, and similar phrases than perhaps in any other department of medicine. The reason is that electricity is a most powerful agent, and is known to do good both by those who profess to a knowledge of its action and by those who have sought relief by its agency. The professors of the art have generally been ignorant of its mode

* 1786. † 1791. ‡ 1831.

of action and unable or unwilling to distinguish the cases in which it should be used or the reverse, and have exaggerated its marvellous and all-healing powers for their own pecuniary advantage. Ignorance of the mode of action of electricity would be excusable if acknowledged, for we are still ignorant of the cause of many of the effects it produces, but one of the characteristics of the ignorant impostor is the glibness with which he explains and attempts to demonstrate the mode of action.

The former electrical treatment was of course purely empirical, a mere matter of chance, and intelligent medical and scientific men, appreciating this, and knowing of no laws or principles upon which the treatment could be applied, ignored its use entirely; and the knowledge of many of the wonderful effects derived by treatment with electricity a hundred years ago has now faded into oblivion and is unknown to the practitioner of the present day. But the art has been practised and preserved by quacks with the result of much imposition on the public.

The latest accepted theory concerning the nature of sound, heat, light, and electricity is that they are all manifestations of motion—vibrations of a subtle imponderable material, called ether, which is supposed to pervade all

space and fill up the interstices left between the constituent molecules of all matter. The molecules of which all things are composed are of a spheroidal form, and therefore, however small and closely they may be packed, of necessity leave interstices.

There is this difference in the production of sound and that of heat, light, or electricity. The vibration of elastic bodies only can produce the sensation of sound, and these vibrations have to be transmitted through some *ponderable* medium such as air, gases, vapours, liquids, or solids. The number of vibrations differs with the pitch. The number of vibrations necessary for the production of audible sound is much lower than the number of vibrations of ether necessary to produce heat, light, or electricity, and the range from the deepest to the most acute sound is according to Helmholtz from 30 to 38,000 vibrations per second. The vibrations of elastic bodies producing sound are transmitted to and produce a vibratory motion in the ponderable molecules composing matter, and these vibrations are comparatively slow. In the case of heat it is assumed that the imponderable elastic ether, to which I have before referred, is in a state of rapid vibration, and that these vibrations, transmitted to material objects, set their molecules into more

rapid motion and thus increase their temperature. When the motion of the particles of undulating ether approaches a rapidity of several hundred of millions of millions per second heat of various intensity is produced; when the number of undulations increases up to about double the rate which produces heat we have the various tints of light which are capable of being appreciated by the optic nerve. "The optic nerve is insensible to a large number of vibrations. It can apprehend only those waves that form the visible spectrum. If the rate of undulation be slower than the red or faster than the violet, though intense motion may pass through the humours of the eye and fall upon the retina, yet we shall be utterly unconscious of the fact, for the optic nerve cannot take up and respond to the rate of vibrations which exist beyond the visible spectrum in both directions." (Ganot.)

When lecturing before the Royal College of Physicians in 1847 Dr Golding Bird alluded to the possibility of electricity being dependent upon ether assuming vibratory movements differing in amplitude and velocity from those producing light, heat, and photographic effects. Faraday upheld the *molecular theory* with regard to electricity, that is, that it is due to certain peculiar conditions of the molecules of bodies

that have been rubbed or heated or acted upon by light; or of the ether which is believed to almost surround these molecules. Since then Prof. Clerk Maxwell has proposed the theory that the phenomena of electric currents and magnets are due to rotations, streams, or other forms of movement in the particles of ether, while light is due to vibrations of it to and fro. In 1845 Faraday discovered that a ray of light polarised in a certain plane can be rotated by the action of a magnet so that the vibrations are executed in a different plane. If iron filings be magnetised they can be seen to rotate and place themselves endways; they then act as a magnet until shaken up. "There seems indeed reason to think that magnets may be merely made up of rotating portions of electrified matter" (Prof. Silvanus Thompson). The above theories of electricity and magnetism are very different to the old notion of fluids.

Electricity, therefore, is not a substance, but *an induced condition of matter* and a condition which can be transferred from one body to another.

To say the least, the relations between sound, heat, light, and electricity are so remarkable that one can never be excited without calling into existence one or all of the others. Heat produces electrical currents and by galvanic action the

most intense degree of heat hitherto known has been obtained. We are all at present conversant with the luminous properties of electricity. One of the most extraordinary relations between light and electricity was discovered in 1875. The metal selenium was found to change its electrical resistance under the influence of light. When properly prepared a sheet of selenium which offers a resistance of 300 ohms in the dark when exposed to the sunlight has a resistance of only 150 ohms. The greater the light the greater the reduction of resistance. This fact has led to the construction of the *photophone*, by which sound is transmitted to a distance by a beam of light. The sound of the voice is made to throw into vibration a thin mirror from which a beam of light is transmitted to a receiver, at a distance, made of selenium on which it falls with varying intensity, thus affecting the selenium, which is connected in circuit with a small battery and a Bell telephone in which the sounds are reproduced by the vibrations of the current.

It has been recently realised that all true solid conductors of electricity must be opaque to light.*

But electricity will also produce sound. When a strong electric current is passed through

* The above facts have been obtained from Prof. Silvanus Thompson's work upon 'Electricity and Magnetism.'

a rod of soft iron, a distinct sound is produced at the closing and opening of the current. This sound has been attributed to the vibratory motion produced in the molecules of the iron by their magnetisation and demagnetisation.

All physicians recognise the influence exerted upon health and disease by heat, light, and motion in the form of exercise, but very little attention has been paid to the place which electricity occupies in regulating the action of the vital processes. That it has a great influence upon the maintenance of health and the production of disease I shall try to prove by argument in a subsequent part of my thesis, but I must first apply myself to carrying out the task I have undertaken, that is, to show briefly the advance made in the application of electricity to medicine during the last 100 years. We have now more accurate means of measuring electricity and have a more perfect knowledge of its action, but although much has still to be learnt under this head, we are altogether in a far better position for employing its effects in the treatment of disease.

Concerning the Manner of its Application.

I have very little fresh information to add with regard to the treatment by statical electricity. The manner of its application is the same now as was employed at the time Dr Steavenson wrote his thesis and is therein fully described.* But this mode of treatment was used for many years after the introduction of galvanism and faradism as the most preferable, and long lists of cases were published in the 'Guy's Hospital Reports,' by Addison,† Golding Bird,‡ and Sir Wm. Gull,§ in which its use was followed by most satisfactory results. But now it has fallen very much into disuse, the constant and interrupted currents having been found so greatly superior in the ease with which they can be applied and also more beneficial in the treatment or relief of diseases dependent upon evident organic changes. But in those diseases which are only functional, and in certain abnormal conditions of the system (*e.g.* hysteria, nerve-prostration), I think that possibly statical electricity in the form of the positive electric charge‖ will be found very useful. Now

* Op. cit., p. 5.

† 'Guy's Hosp. Reports,' 1837, No. 2.

‡ Ibid., 1841. § Ibid., 1852–53.

‖ This method, in the thesis of 1778, is called *Insulation.*

that the electroscope will show clearly the electrical condition of every patient, the indication for such treatment becomes at once intelligible and easy of application.

In the application of galvanism and faradism the resistance offered by the skin to the penetration of the current has to be taken into consideration. This resistance varies much in different individuals and at different times in the same individual, a warm moist skin conducting better than a dry and cold one. The average resistance offered by the skin has been stated to be equal to about 2500 ohms or about 76 miles of copper wire of one millimetre diameter. In the application of electricity this resistance can be very much reduced by well moistening the skin with warm water, and better still with warm salt water; saline solutions conduct electricity much better than pure water. Where the skin is thick, as on the hands and soles of the feet, the resistance offered is much greater than in other parts of the body. If we want simply to influence the skin and do not want the current to penetrate to the muscles or deeper parts it is best to let the skin remain unmoistened. The body when immersed in water, as in an electric bath, is a better conductor than the water surrounding it, and a current of electricity sent through the bath will penetrate and traverse the

human body, but if salt be added to the water, the solution will then become the better conductor and the current will traverse it and not enter the body at all.

The weather also has a great effect upon the resistance of the human body, possibly by its effect on the condition of the skin. Lunatics, whose skins are in some forms of mental disease unnaturally harsh and dry, offer an extraordinary amount of resistance to the passage of an electric current. Very frequently patients say that the degree of paralysis and the sensation in a paralysed part are very much affected by changes in the weather, as is also the resistance. In warm weather or when a change takes place from cold to warmer weather an improvement in the paralysis is experienced; and on the contrary when a cold day supervenes on warmer weather the paralysis is worse and the muscles feel stiff and contracted.

When two electrodes are placed upon the body and a current is passed of sufficient strength to penetrate the skin, the current will pass from the positive electrode to the negative one, but in its passage it is diffused in the form of curves spreading out until a point midway between the two electrodes is reached, when it begins to converge again towards the negative electrode. The

greatest intensity of the current traverses a direct line between the two electrodes, but the farther they are apart from one another the more the current is weakened on account of its greater diffusion.

To produce an effect upon an organ therefore the more the current can be localised the greater is the influence exerted. A weak and therefore often painless current can be used if applied locally, but if not so applied a much stronger current would be required to produce the same effect and one perhaps not able to be borne without an anæsthetic. Many of the good results of electricity have been unattained and entirely disbelieved in because the current has been passed through the body in a haphazard way, often with the patient only holding the handles of some kind of electrical machine, which has produced most uncomfortable sensations and sometimes pain, with very little appreciable effect upon the organ it was wished to influence and which possibly was situated in some remote part of the body.

Different methods are employed in applying galvanism and faradism according to the texture it is wished to influence and also for the effect it is desired to produce.

Duchenne, who almost exclusively used the interrupted current, followed what is called "direct

faradisation;" that is, he applied both electrodes to the surface of the muscle he wished to influence. If the electrodes were not large enough to cover the whole surface of the muscle he applied them successively to all parts of it. The "indirect method" which was proposed by Remak and carried out by Ziemssen, consists of placing one electrode on an indifferent part of the body and applying the other to the "motor point" of the muscle it is wished to influence.

For diagnostic purposes, that is, for determining the electro-contractility of a muscle, a combination of the two methods just mentioned is advisable, namely, placing one electrode on the "motor point" and the other upon the muscle itself. When it is wanted only to influence the skin one moist electrode should be placed on an indifferent part of the body and the other, a dry one, should be applied lightly to the affected part, the skin also remaining dry.

For general faradisation one electrode may be placed on an indifferent part of the body, or the feet placed on a metallic plate, and the whole surface of the body sponged over with the other electrode.

In the use of galvanism for treatment two methods are followed; one the "stabile" when both electrodes are kept perfectly stationary, the

current passing evenly between the two points; and the other the "mobile," when usually the negative electrode is moved over the limb or the part it is wished to influence. In both methods it is usual for one electrode to be placed on an indifferent part of the body. The most convenient electrode for this purpose is an oval plate of pliable metal such as tin with a layer of amadou to retain the moisture, and all covered by a piece of wash-leather or flannel with a waterproof back to protect the patient's clothes.

If the galvanic current be employed for stimulating muscle to contract, as when for diagnostic purposes it is required to elicit the reaction of degeneration or prove its absence, it must be interrupted, for contractions only occur at the moment of making or breaking the current. The direction of the current is not of so much importance as the position of the poles. The greatest chemical and thermal action taking place at the negative pole and, in healthy muscle, the strongest contraction also takes place at the point of the application of the negative pole.

What is called "central galvanisation" consists in applying the negative electrode in succession to the nervous centres, the brain, spinal cord, and sympathetic in the neck; the other electrode being placed on the epigastrium or some other remote

part of the body. This method of electrisation is generally employed when it is sought to influence the whole nervous system, as in states of great nervous depression or exhaustion after long illnesses, or in cases of nervous insomnia.

I have omitted to mention the many applications of electricity to surgery as not coming within the scope of a medical thesis.

Concerning its Manner of Working.

A hundred years ago, when only statical electricity was known, it was suspected that it exercised some influence upon the human body other than that of a stimulant.* The electrolytic power of electricity† had not been discovered, although to it, possibly, was due many of the formerly considered marvellous phenomena. The fact that the galvanic current decomposed chemical compounds enabled Davy, in 1807, to isolate several additional elements, such as sodium and potassium. Since then numerous properties have been detected as belonging to electricity. Those affecting the human body have been divided into

* 'De Electricitate,' 1778, p. 13.

† In 1789 it was first discovered that water could be decomposed by passing through it a series of discharges of statical electricity.

mechanical, physical, chemical, and physiological. The first three affect both organic and inorganic matter, but not in the same way, the presence of life modifies the action; but the physiological effects of electricity are peculiar to living beings, and are simply modifications of the ordinary vital processes. Electricity may increase, diminish, arrest, or otherwise modify their action; it affects secretion and excretion, absorption, reflex action, and nutrition.

The physiological action of the induced current is almost *nil*. The duration of the transit of the current is not sufficient to produce any of the characteristic effects of the passage of a current of electricity, and the currents are alternately in a reverse direction. They only produce a momentary contraction of muscular tissue as is produced at every make and break of a constant current. But the makes and breaks are so rapid that the muscle has not time enough to relax between each, and a prolonged tonic contraction results as long as the application of the electricity is continued, or until the muscle relaxes through sheer exhaustion.

Although perhaps the induced current may reduce the amount of blood flowing to a part during its application by causing contraction of the muscular coats of the vessels, there is no doubt

that after the application has ceased a re-action sets in and a warmth is experienced in the part of the body operated upon through dilatation of the vessels and the consequent freer supply of blood to the part. But the physiological action of the constant current is of a much more complex nature, and is not yet thoroughly understood. But it is probable that it does not produce relaxation of muscular contractions and therefore cannot be said to have a distinctly opposite effect to the induced current. There is no doubt it induces an increased flow of blood to a part of the body included in the circuit, especially at the neighbourhood of the application of the electrodes, and there must be a corresponding dilatation of the vessels to allow of this increased supply of blood. But whether the dilatation of the vessels is due to a relaxing influence the current has on their muscular coats or the chemical changes produced in the tissues supplied by those vessels and necessitating a freer supply of blood is an undecided question.

The constant current does produce contraction of muscular tissue, just as the induced current does, at every make and break, but the redness of the part is produced if a moderate current as regards strength is allowed to flow continuously for a very short time, the previous or subsequent

making and breaking of the current appearing to have no effect upon it.

It is probable that changes are induced in the ultimate tissue cells of a part exposed to a constant current of electricity analogous to the chemical action produced in the electrolysis of water. If the current is weak the process does not go so far as splitting up the watery parts of the cell into oxygen and hydrogen, but produces some sort of activity in the cell not present there before. It increases or alters the character of the secretion of the cells composing secreting glands as evidenced by the increase of saliva and metallic taste in the mouth produced by the application of a continuous current of electricity anywhere in the neighbourhood of the salivary glands. This probable increased cellular activity, the quickening of the building up and destruction of cells never-ceasingly going on in the living body, is sufficient to account for the increased demand for blood required for these changes, and the resulting increased supply afforded by the dilatation of the capillaries. The capillaries do not dilate by any power possessed by the constant current to cause muscular relaxation, but secondarily through nervous influence excited by the demand produced in the cells for more blood. The action of the constant current upon muscular tissue, if anything

beyond, besides inducing these probable changes in the ultimate muscular elements leading to increased activity in the ultimate cells, increased nutrition, and therefore increased tone (as it is called), is probably to induce contraction rather than relaxation.

In considering these changes in the cellular elements of the body and in the blood supply the osmotic power of electricity must not be forgotten. It has been found that if two fluids of different densities be divided by a porous diaphragm and an electric current be made to pass through them osmosis takes place in the direction of the current. If the current passes from the lighter to the denser fluid the natural osmotic action is increased; but if the current passes in the reverse direction the osmotic action is reversed, the denser fluid passing through the diaphragm into the less dense. The osmotic power of electricity probably explains the influence of galvanism in causing the absorption of fluid effused into joints or serous cavities when applied in such cases.

In a recent paper on the formation of uric acid Dr Latham, the Downing Professor of Medicine in this University, has sought to prove that the presence of uric acid in the blood is due to the imperfect metabolism of glycocine, which takes place under certain conditions, one being an

insufficient amount of exercise. When a proper amount of exercise is taken the glycocine is transformed into urea and normally eliminated by the kidneys. He has also sought to prove that this more-to-be-desired metabolisis is dependent upon a due amount of nerve force, and that the production of nerve force is encouraged by exercise. It has also been proved that the contraction of muscle produces electrical currents. After passing on to describe the electrolysis of urea carried out by Professor Dewar, also of this University, Professor Latham makes the interesting remark that "if there be any correspondence at all between nerve force and the electrical current, this experiment possesses great significance."

As a matter of fact we do not know what nerve force is or what electricity is; they are both possibly modifications of motion as has been suggested is the case with heat and light. All we know is that the only distinctly appreciable change in a nerve during the passage of a nervous impulse is an electrical one (Michael Foster). It would be a happy result of the inquiries above alluded to if in the future we should be able to prevent gout by the application of electricity.

In many cases, it seems to me, the natural nervous force or impulse, as it is called, is almost wanting or very much reduced in strength.

Such cases occur after very severe and prostrating illnesses, and also in persons who from some cause or other, such as mental strain, anxiety, grief, exhaustion from bodily exertion, and the like, are brought down to a condition which is called "being below par." In some families this condition of health, or non-health, seems to be constitutional, many members being characterised by an apathetic phlegmatic temperament, to whom the performance of any of the active vocations of life seems a trouble; they want rousing and influencing by some unwonted stimulus to make them take an interest in, or do, anything. In many such people I have observed conditions which have led me to suppose that the natural nerve force or current is decreased in amount. Although their electro-sensibility is not impaired or the resistance they offer to electricity increased, it requires a much stronger current than usual to produce muscular contraction, and therefore I should argue, that it requires a much greater mental effort or a much greater excitement for the production of electrical separation (when artificial stimuli are not applied) to produce muscular contraction or mental activity of any sort. The normal amount of electrical separation going on in the body is reduced in quantity, or the centres for producing electrical separation (if

such exist) are not executing their function to the full extent. I can suppose that such a centre for electrical separation does exist and that it is most likely situated in the medulla. I have noticed this reduction in electrical excitability especially to follow severe cases of typhoid fever while patients are in that childish and semi-idiotic state which not so very infrequently accompanies convalescence from that disease. And general galvanisation quickly restores such persons to a proper nervous and mental condition, gives them courage and buoyancy of spirits, and generally improves their nervous tone. But it is not necessary to demonstrate the presence of an electric centre in the human body to argue that electrical separation does, and is continually taking place. McKendrick, who denies the existence of such a centre to all but a few fishes and animals, allows that electrical separation takes place in the muscles at the moment of contraction and in the retina of the eye on the incidence of light, due in his opinion to chemical changes. All the vital processes of the body, the building up and degeneration of the tissues, digestion and secretion, are accompanied and carried out by the means of chemical processes, and in this human laboratory is it to be maintained that all these chemical reactions take place without the production of

electrical separation? On the other hand, in reality, may not the body be looked upon as a collection of innumerable small batteries continually splitting up electricity into its positive and negative components?

In living nerve there is always a natural nerve current which can be detected by a galvanometer. The only change we are at present cognisant of as accompanying a nervous impulse is a negative variation of this natural nerve current. It is not dependent on the nature of the stimulus which produces the nerve impulse, that is, it may be chemical, mechanical, or electrical, or from one of those modifications of motion known as sound, light, or heat. Of the nature of the action of organic or vital stimuli we know very little (Michael Foster). The rate of travelling of the negative variation along a nerve is 28 metres per second and is identical with the rate of travelling of a nervous impulse. The negative variation passes in the form of a wave. The whole wave takes ·0007 of a second to pass any given point of a nerve. The length of the wave is 18 millimetres. Therefore a nervous impulse is a molecular disturbance propagated along the nerve in the form of a wave of the length of 18 millimetres and possessing a velocity of 28 metres per second.

The experiments of physiologists of the present

day on the action of electricity upon nerves and the natural nerve currents have been confined to the action of dynamic electricity in the form of the constant current or the interrupted current. I can find no experiments as to the electrotonic condition of nerves under the application of statical electricity; for example when a length of nerve is charged positively. When a constant current is passed we know that the normal nerve current is increased about the region of the positive pole. This corresponds to the observed action of a positive charge in improving the general nervous tone of the body. The negative charge produces a condition of body as of utter prostration, similar to that produced by blood-letting, and similar to those conditions I have described as accompanying great prostration from severe illness or other causes when the irritability or normal condition of the nerves has deteriorated, the natural nerve current diminished, or the nerves are in a condition of permanent decreased excitability.

The relationship between electricity and nerve force has given rise to much controversy. Sir John Herschel* hints at this relationship and supposes that the brain may be either the organ of secretion or at least of the application of the *vis nervosa;* he remarks, "If the brain be an

* 'Discourses on the Study of Natural Philosophy.'

electric pile constantly in action, it may be conceived to discharge itself at regular intervals, when the tension of the electricity reaches a certain point along the nerves which communicate with the heart and thus to excite the pulsations of that organ." Dr Arnott also hinted at some such cause being the active agent in keeping up the regular pulsations of the heart.

Dr Golding Bird did not believe in the identity of electricity and nerve force, but believed that as electricity will excite magnetism in a bar of soft iron so will electricity excite nerve force in the brain or nervous cords. Drs Beard and Rockwell in their work on 'Medical Electricity' say that "between the behaviour of electricity in animal bodies (animal electricity), electricity in general (statical and dynamical electricity) and magnetism there are analogies so close and so consistent as to warrant the view that all are but *different manifestations of one force*." Dr Vivian Poore says that "the inference has been, by some, too hastily drawn, that nerve force and electrical force are identical. That the two forces are related in so far that the one most readily excites the other there can be no doubt, and that they are very closely correlated there is every reason to believe, but that they are not identical the following reflections seem to show:

"1. The rapidity of the transmission differs—that of electricity being estimated at 462,000,000 of feet per second, and that of nerve force at only about 200 feet per second.

"2. Nerve force is not conductible along a metallic wire.

"3. Cold diminishes the conducting power of nerves for nerve force, whereas it increases the conducting power of solids or fluids for electricity.

"4. The crushing or compression of a nerve destroys its conductivity. It may be, however, that the crushing of a nerve is analogous to the breaking of the copper conductor in an insulated telegraph wire."

To this it should be added that when a current of electricity is passed along a nerve it only travels at the same rate as nerve force. And the argument that a ligature placed upon a nerve arrests the passage of a nerve impulse, and would not arrest an electric current, is not altogether true, for an electric current of low tension passed along a nerve can be stopped by the application of a ligature.

Dr Michael Foster dismisses this question by asserting that "of the nature of the action of organic or vital stimuli we know very little."

One of the most interesting facts connected with

the influence of electricity upon nerve force has been shown by experiments carried out by Dr Poore. He has proved that the passage of the continuous current through muscles or the nerves supplying them, increases their susceptibility to the stimulus of the will, and also their endurance for voluntary muscular action. He found that a weight of seventeen ounces could be held out in the hand at right angles to the body for double the time when a constant current was passed through the arm than when no electricity was used. He also found that the force of voluntary muscular action measured by the dynamometer could be very greatly increased by the passage through the arm of a galvanic current. It was found that galvanism increased the force of the squeeze of his own hand about eleven pounds. A greater increase was obtained in experiments upon other individuals. This property of the constant current in restoring the excitability of exhausted muscles has been called its *refreshing effect.*

We have of late years begun to recognise the influence of the physical phenomena upon the conditions of health and disease. We know that the humidity of a locality as affected by the subsoil drainage has more influence upon the prevalence of phthisis than any amount of hereditary predisposition or abundance of bacilli; that the baro-

metric pressure influences the blood pressure; that electrical changes in the atmosphere, as on the approach of a thunderstorm, influence strongly many persons possessed of delicately strung nerves; that sound in the form of music has also an influence upon the circulation, no doubt through the vaso-motor system, but how that system is affected by music we do not at present understand. We also know that the varying vibrations of ether producing light of different colours have a great influence in the treatment of the insane. How these several influences act we are not as yet able to explain. The difference produced in highly sensitive or nervous people by sudden and marked changes in the weather, especially sudden changes of temperature to which this climate is so liable, is due to the electric changes produced in the individual.

It is a well-known and recognised fact that a few hot days in succession so change the electrical condition of the surface of the earth that a thunderstorm is often necessary to restore equilibrium. It is impossible for human beings to remain at a position of zero with regard to electrical potential when the potential of every object around is varying. Induction alone would produce electrical separation. It is fortunate for us we live in a climate with the atmosphere so

charged with moisture that the varying electrical conditions can be more easily equalised. If such sudden changes of temperature took place in countries with a dry atmosphere the inhabitants would suffer considerably. Perhaps these climatic conditions have more influence in producing the peculiar characteristics of race than has been supposed. The self-possession and undemonstrative demeanour of an Englishman may be due to the more ready equalisation of electrical disturbances, and the excited and vivacious tendencies of the denizens of more southern climes to an absence of the chief means for restoring equilibrium. In those parts of the earth where the air is very dry the manifestations of animal electricity recorded are almost incredible to the inhabitants of these islands. Rubbing the feet a few times on the carpet will enable an inhabitant of the Southern States of America to light the gas by the spark which will pass when he presents his finger to the metal point of a gas burner; and electrical displays are produced by combing the hair, which a moist atmosphere alone prevents us from perceiving in this country.

There are good reasons for believing that the electrical conditions of the atmosphere influence health. I have deferred reading my thesis hoping to have had more leisure or opportunity for ob-

servation and experiment. I hoped to have been in possession of incontrovertible facts that electrical conditions of the atmosphere *do* influence health. I can now only argue from what has already been written that *it is likely* that they do so and show in what direction I hope to be able to prosecute inquiry. I have therefore to resort to the observations of others and can only draw deductions from the facts which they detail. But these facts in many instances bear out the statements of eminent observers quoted in my former thesis.* If they be compared with the facts recently discovered concerning atmospheric electricity and terrestial magnetism they will in many instances be found to correspond. But this result seems to me to be certain, that if differences in the electrical condition of the earth do take place and are continually taking place, a highly sensitive organism such as the human body must participate and take cognisance of these changes, and it is not too much to suppose that these changes have some influence upon health.

To put my proposition in another way. All conditions of the atmosphere which have been noticed to influence health prejudicially are accompanied by a development or increase in the amount of negative electricity. Before a thunder-

* 'Spasmodic Asthma,' 1879.

storm, when many people of a delicate nervous temperament assert that they feel indescribable "malaise" and oppression, the atmosphere in the neighbourhood of the earth is negatively electrified, and I have known ladies made to feel extremely ill when attending a lecture on electricity accompanied by experiments when a large amount of free electricity has been produced. The positive variety being more easily conducted away there remains an undue amount of negative electricity.

In my thesis on Asthma for the M.B. degree I hinted that possibly the varying electrical conditions of the atmosphere might explain the seemingly unaccountable conditions which influence and produce an attack of the disease.* Since then the struggle for existence which young physicians have to maintain has prevented me devoting the time I could have wished to investigate this theory further, nor am I able to discover that very much additional knowledge has been obtained by those who have had time to prosecute investigation. "We know that the electrical potentials of different places on and in the earth differ considerably, sometimes to the extent of

* 'Spasmodic Asthma.' A thesis for the M.B. degree of the University of Cambridge. By W. E. Steavenson. Cambridge: Deighton, Bell & Co. 2nd edition, pp. 9-17.

several hundred volts."* "We obtain this information from the currents observed to flow through wires joining parts of the earth widely separated."† "Electrified masses of air moving at no great distance from the earth's surface are continually altering the distribution of electricity," "which is, however, generally found to be negative on the earth's surface."

Sir William Thompson found that the potential of the air varied very rapidly near the surface of the earth. Thus he has observed a difference of potential between the earth and the air nine feet above it, equal to 430 volts in ordinary fair weather, and in breezes from the east‡ and north-east as great a difference as this per foot of air. The potential is perpetually fluctuating, even in fair weather. "The potential of the air appears to be generally positive in fine weather, and negative only during broken or rainy weather."

These recent observations point in addition to the suggestions I have made in my former thesis that the negative variety of electricity has a deleterious effect upon health.§ I believe I have produced a fit of asthma by charging myself with

* The electricity produced by one Daniell's cell=1·08 volts.

† 'Electricity and Magnetism.' By Prof. Fleming Jenkin, F.R.S.

‡ Thesis on 'Spasmodic Asthma,' p. 16.

§ P. 9, ibid.

negative electricity. This was the result of accident, as at the time I made the experiment I was under the impression that I was charging myself positively. The unpleasant result has not encouraged me to repeat the operation. Another member of this University, who suffers from asthma, tells me that he experienced a similar result when charging himself with electricity in the Cavendish Laboratory.*

In delicate individuals and persons of a nervous temperament the changes of weather, and especially an east wind, are known by common observation to act prejudicially. I know that attempts have been made to account for these effects in other ways. The recent observations of the daily variations of terrestial magnetism† accord very closely with the electrical changes by which I have tried to account for the periodicity and the exacerbations of dyspnœa in asthma.‡

* See also a case mentioned by Sir Thos. Watson in his lecture on "Asthma" in the 'Principles and Practice of Physic,' in which galvanism produced an attack of the disease.

† 'Electricity and Magnetism.' Prof. Silvanus Thompson, p. 120, 4th edition, 1883.

‡ Vide 'Spasmodic Asthma,' pp. 9, 10.

Diurnal variations of positive electricity in the atmosphere.	Ganot.	Quetelet at Brussels.	Stewart at Kew.	Daily variations of the barometer.*
1st minimum	Before sunrise, 3 to 6 a.m.	Midnight	—	Lowest, 4 a.m.
1st maximum	11 a.m.	8 to 10 a.m.	8 to 10 a.m.	Highest, 10 a.m.
2nd minimum	A few hours before sunset, 3 p.m.	3 p.m.	—	Lowest, 4 p.m.
2nd maximum	Sunset to 9 p.m.	6 to 9 p.m.	7 to 10 p.m.	Highest, 10 p.m.

* The same in all latitudes, but difficult to detect in the temperate zones as they occur in conjunction with accidental variations (Ganot).

In our climate the south-west winds, which are usually warm and therefore light, cause a fall in the barometer, and they are also usually charged with moisture from evaporation from the vast expanse of ocean they pass over and are therefore charged with positive electricity.

The east and north-east winds are cold and dry from passing over vast continents and are therefore denser, and cause a rise in the barometer and are usually accompanied by an increase in the negative electricity.

The predominance of positive electricity in foggy weather is the cause I have assigned for the

immunity then experienced from attacks of pure nervous asthma, though the ordinary dyspnœa accompanying bronchitis and emphysema is often increased.

When we consider that every vital process is most likely accompanied by the production of free electricity in our bodies,—that the incidence of every ray of light upon the retina,* our every act of thought, and certainly our every muscular movement has been proved to produce electrical currents; is it possible that the varying electrical conditions of the atmosphere can take place without influencing our systems? The electrical separation taking place in the human body is of a kind intended to counteract as much as possible the changes likely to be induced by the atmospheric electricity so that the normal functions of the body may not be unduly interfered with or arrested.

Although the earth and inanimate objects upon it are usually negatively electrified, human beings in a state of health are almost invariably found to be positive. When the body is insulated the electrical condition is easily made manifest by the use of a condensing electroscope. Dr Poore in his work on 'Electricity in Medicine and Surgery'

* Prof. McKendrick on 'Animal Electricity,' before the British Association for the Advancement of Science, September, 1883.

says, "It is remarkable that hardly any two persons are in the same condition electrically, and nervous irritable people are said to exhibit a more active electrical condition than persons of a phlegmatic temperament." Dr Golding Bird in his lectures before the Royal College of Physicians in 1847 attributes this existence of free electricity in the human body chiefly to evaporation and respiration and he sums up his observations on this point under the three following heads. That electricity exists in the human body:—

"1st. In a state of equilibrium, common to all forms of ponderable matter.

"2nd. In a state of tension capable of acting on the electrometer, giving to the whole body a generally positive condition, and arising in all probability from the disturbance of the normal electrical equilibrium by the process of evaporation and respiration.

"3rd. In a state of current, a dynamic condition, arising from the disturbance of equilibrium by the union of carbon with oxygen in the capillary system, and from other chemical processes going on in the body; such currents, although suspected to be everywhere existing, having been actually detected between the skin and mucous membrane, the stomach and liver, and the interior and exterior of muscular structures."

The good results derived from the use of statical electricity were probably misunderstood and did not depend upon the shocks given to the system of the individual but to the preliminary charging of the patient with the electric fluid which possibly counteracted the electric condition on which the illness of the patient depended; the morbid condition depending on the presence of an accumulation of negative electricity. As a matter of fact most patients when charged were charged positively.

Should I be able by future experiment to prove, what I very much suspect to be the case, that negative electricity exercises a baneful influence upon health and that many of the conditions of ill-health and depressed vital energy are associated with the development or presence of an increased amount of negative electricity in the human body, the form of treatment by statical electricity will again come into vogue and the electroscope will become an indispensable adjunct to the many instruments now employed in physical diagnosis.