ELECTRO-PATHOLOGY

AND

THERAPEUTICS

AN ACCOUNT OF MANY YEARS' RESEARCH WORK; THE DISCOVERY OF THE ELECTRO-PATHOLOGY OF LOCAL PYREXIA, AND OF AN EFFECTIVE MEANS OF STAYING INFLAMMATION.

BY

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TOGETHER WITH A

PREFATORY TREATISE

UPON

THE NERVOUS SYSTEM IN ITS RELATION TO NEURO-ELECTRICITY

BY

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PREFACE

The object of this treatise is to present to the medical profession and the general public the results of at least thirty years' research work with instruments of precision. The work has been done by the joint authors acting independently and until recently without collaboration in the intervals of strenuous commercial and professional life; the microscopical part of the work having been carried out by Dr. Bowman and the electrical by Mr. Baines.

The object of the physiological investigation which forms the first part of the book was to endeavour to determine the nature of the influences which favour the growth and multiplication of inimical organisms, such as bacteria in the blood, and which are a cause and consequence of disease. In doing this the author had at his disposal the very best microscopical instruments. Many of the objectives were specially made for the work by Baker, Powell and Lealand, Ross, Watson and Zeiss, and the range of power went up to 20,000 diameters, so that the objects were as distinct as possible. The general results may be summarised by stating that the determining influences appeared to be temperature and loss of nervous control in the cells and tissues of the organism. A rise in the former also seemed to depend on the latter condition. As an electrician, the investigator knew the dependence of the nerve power upon its conducting qualities, but it was not until the joint authors met and discussed the subject that the full significance of their separate work when combined was apparent. The result was this treatise.

The writer of the second part has, by reason of his special training and facilities for continued experiment, been enabled to recognise and avoid many of the errors into which most of his predecessors appear to have fallen, and he ventures to offer the opinion that absence of adequate knowledge of the electrical system given by Nature to man has rendered the practice of electro-therapeutics little more than experimental. He holds the view that Nature's methods cannot be improved upon, and merely claims for himself that he has endeavoured to understand those methods, and understanding them—in some measure at least—to apply them to the amelioration and cure of a few of the ills which afflict humanity. In reality many of the disorders from which we suffer, many of the affections whose origin is obscure are simply and easily dealt with when their locality, area, and nature are ascertained. The difficulty does not lie in the treatment so much as in diagnosis, and it is in diagnosis that human opinion is so prone to err. There are several instruments of great value to the medical man, the stethoscope, the laryngoscope, the ophthalmoscope, the microscope, and others, but they are not enough. They will not distinguish between chronic constipation, or dyspepsia, and cancer in its early stage: they do not throw any light upon disorders of the brain or diseases of the middle ear, upon St. Vitus' dance, or neurasthenia, or exophthalmic goitre, or give the slightest indication of the nature of the great majority of ailments until they become outwardly apparent.

What is required is an instrument which will enable the practitioner to say, "This is so-and-so" with absolute certainty. At present he frequently finds himself in the position, practically, of being asked to determine a patient's weight without being able to see, or receive a description of, the patient. Small wonder, then, that the nature of the complaint is not recognised; that it is often merely guessed at.

In the future the new method of diagnosis will become universal, and in the hands of a large number of scientific men will do a great deal to revolutionise the practice of medicine as it is to day. The writers have not been able to accomplish much; a lifetime is all too short for that. But if they succeed in some degree in pointing to the way they will be content.

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PART I

THE NERVOUS SYSTEM IN ITS RELATION TO NEURO-ELECTRICITY

THE FUNCTION OF NERVES IN THE HUMAN BODY.

THE human body is the most complicated and delicately organised structure known to man. The whole has its primary origin in two germ cells, which represent the male and female elements, and their fusion in the ovum originates the metabolic changes by means of which the primary cells are caused to multiply and differentiate so as to evolve the various parts and organs of the body. These may be considered as forming five different systems, mutually dependent, viz.,—

1. *The skeleton*, which gives the necessary rigidity and protection to the more delicate organs.
2. *The muscular system*, which is attached to the bones, and enables them to move under the action of stimulus or volition.
3. *The nutritive system*, which provides for the reception of food and for its digestion and assimilation.
4. *The arterial, venous, and lymphatic systems*, which by the circulation of the blood supply the formative material and remove the waste products.
5. *The nervous system*, which controls the motions, and regulates the metabolic changes in the various organs, as well as harmonises the action of the whole.

The nervous system is that which is most important to the subject-matter of this treatise, and therefore requires special consideration.

It forms a most complicated set of links between the various parts of the body, and for the purpose of closer study may be said to consist of the following divisions:—

a. The central nervous system, which is formed by the brain with its extension in the spinal cord.

b. The distributing system, which includes the cranial and spinal nerves, and the nerves of the special sense organs.

c. The motor and automatic nerves.

d. The sympathetic system, which co-ordinates the action of the whole.

The central nervous system, the most important portion of which is the brain, is in all vertebrated animals, including man, situated within the cranium or skull, which is the apex of the spinal column, of which it forms a part.

It is a large and complicated mass of nervous and ganglionic substance, and may be considered as divisible into: (1) the great brain or cerebrum, which occupies the front and upper part of the skull, and overlaps (2) the hind brain or cerebellum; and (3) the medulla oblongata, which form the transitional part between the spinal cord and the various parts of the brain.

Each of these parts has its special structure and functions. The protection of the brain is secured by the whole being enclosed within a smooth membrane, which consists of three distinct layers lining the interior of the skull.

The *cerebrum* is the largest and most highly developed part, and is, so far as any material organ can be said to be the medium, the portion which is the seat of mental, moral, and voluntary action, since its greatest development is always found where these qualities are most in evidence. Here too are situated the organs in which the energy is generated which works and controls the voluntary and automatic actions which are necessary to the perfect fulfilment of the various functions of the body. It corresponds in this respect to the generating station of an electric installation, while the *cerebellum* and interior connections with the brain and spinal cord resemble the switch board of the power house, and the *medulla oblongata* with its spinal extension represents the trunk main for distribution, and from which all the nerves serving the separate parts of the body originate and proceed.

In addition to the larger divisions of the brain, as mentioned above, experiment has proved that there are special relations between various parts of the body and definite areas or volumes of the brain; and all the parts of the brain are themselves connected and inter-connected with each other so intimately that probably every part is in sympathetic action with the molecular changes which are occurring in any other part. The brain is duplicated on each side of a deep vertical fissure which divides it longitudinally, and the nerves, whether cerebral or central, are extended into each lobe and are crossed from one to the other. The surface of each lobe is formed of an immense number of intricate convolutions, the total area of the whole surface being very large. The brain of an average man weighs about 48 ozs., and of a woman 43, but they have about the same proportion in relation to the total weight of their respective bodies.

Great brain power and activity appear to depend more on density and convolution than volume.

Apart from the spinal cord there are, however, a series of nerves which proceed direct from the brain, and are therefore called *cranial nerves*, and these are mostly concerned with the supply of the senses and other organs directly connected with the head. Twelve pairs of these nerves are distinctly recognisable.

The spinal cord, which proceeds from the medulla oblongata, lies or is enclosed in the canal formed by the vertebræ of the backbone, and reaches down to the lower margin of the first lumbar vertebra. It is a mass of nervous matter formed of a large series of nerve fibres, which are associated together, and which branch off to the various portions of the body, and are always double: those which convey impressions to the centres are termed afferent, and those which convey influences away from the centres are called efferent. Each branch nerve as it leaves the spinal cord has a double origin, one portion from the posterior being sensory nerves, and the other from the anterior portion of the cord are the motor nerves. These pass through openings in the vertebræ and are distributed to every part of the body, the double trunk nerve becoming smaller as it proceeds until the utmost limits of the organ are reached, when the nerves terminate in different forms, depending on their functions, such as fibrillæ or other tactile organs, loops, or bulbs.

The extreme tenuity and delicacy of these terminations can easily be imagined when it is remembered that even each hair of the head and every living cell is in nervous connection with the brain, and that they receive, in addition to sympathetic control, a supply of energy upon which their action and life depend.

In addition to the nervous cords there are at all the great nervous centres a series of enlargements of the nerve fibres, which are termed ganglia. The cells forming the ganglia are generally irregular in form, having a nucleus of protoplasmic matter, and are furnished with processes or arms which spread out and intermingle with each other, connecting together a number of cells by a complicated network of nerve fibres. The nerve cells are always, when in a healthy state, well ionised. In connection with the sympathetic system there is a chain of ganglia down each side of the spine.

These seem to have various functions, as in addition to frequently forming subsidiary stations or distributing centres from which nerves proceed, they evidently act as storage magazines for the neural energy which is necessary for automatic action, and also as directors and stimulators of the metabolic and other changes in the cell contents.

Every portion of the body is therefore in living connection with the great central nervous organ, the brain, which is thus able to direct and control every change as it occurs, and to be in touch with every impression received from without, and especially those such as undue mechanical force or heat, or any other form of stimulus likely to be injurious to any part of the body.

The Origin and Development of the Nerves.

The rudiments of a nervous system make their appearance at an early stage in the ascending scale of animal life.

In the monads, which form the lowest type known, and which are simply protoplasm (which is the physical basis of life) enclosed within a more or less tenacious pellicle or membrane, we have response to stimulus in its most rudimentary form. All parts of the surface seem equally responsive. As we ascend higher we find the sensory areas become more localised, and although there is no definite nervous system forming lines along which sensation can be conveyed, there are more or less sensitive areas or tracts, and even rudimentary sense organs as in the zoophytes. When we reach the worms and lower molluscs we find a more definite nervous system associated with rudimentary sense organs, as seen in pigment spots and the rudimentary eyes. In the higher cuttle fishes and other cephalopods a nervous system is fully established, and the same is observed in the insects and simple invertebrated forms. In the lowest vertebrates the provision of a definite nervous system and sense organs is always found, and in the higher forms, including man, it reaches its most perfect development. A complete and definite nervous system is always associated with the formation and development of *germinal layers* in the embryo. This is always the form taken by the ovum-segmentation, and in the present day we have a typical instance in the amphioxus, which is the earliest form of a vertebrate which has survived unchanged through the ages of geological time.

In this surviving form we see the process of ovum-segmentation, gastrulation, and the formation of the germinal layers which foreshadowed the method of embryological development in all the higher members of the vertebrates.

This treatise is only concerned with the origin and development of the nervous system in man, and to this careful attention must be given.

Man in his whole structure is a true vertebrate, and the whole of his bodily organisation arises from the development of an impregnated ovum in identically the same way as all others in the series, so that they all present a phylogenic unity. It is only in the light of this unity that we can fully interpret the significance of man's place in Nature, and the transcendent position which he occupies as the "foremost in the files of Time and heir of all the ages."

In looking at the development of the human embryo, for our purpose we need only consider the chief element by the unfolding and procession of the psychic apparatus or the sensorium.

This as presented in man consists of two distinct although correlated parts:—

1. The outer membrane or skin, with its sensitive layers and nerve ramifications, including the accessories such as hairs, sweat glands, etc.

2. The central nervous system, with the brain and spinal cord and its extensions, including the peripheral, cerebral, and spinal nerves.

These two lie in the body as far apart from each other as possible, and are only connected by means of a portion of the total peripheral nerve system. It may therefore seem strange that both these have a common origin in one primitive germinal layer which formed the ectoderm or outer surface of the embryonic tube. Their after-separation and the enclosure of the central nervous system within the organism comes at a later time in the development. A little thought, however, convinces us that even the central nervous mechanism must have had its origin in an outer surface of the ancestral body, because there alone could it receive the influence of external environment, and the cells gain the necessary sensitiveness and responsive action to enable them to form the medium for the transmission of external impressions.

It is in this direction that we see the immense gain to our knowledge of the nervous system in man by the consideration of its development in the lower forms of life.

The gradual increase in the size and complexity of organism, and the specialisation which was rendered necessary by increasing requirements and differentiation in the sense organs, gradually forced the two systems further apart, and led to a continual extension of the peripheral nerves so as to keep the two systems in touch with each other for the purpose of harmonious control.

This is clearly seen as we ascend the scale of animal life.

In the protozoa there are no germinal layers in its life-history, and even in the metazoa the functions are all exercised by means of simple visceral and cutaneous membranes.

When we come to animals a little higher in the scale it is seen that groups of sensitive nerve cells are separated from those forming the basis of the epidermis, and retire into the deeper layers, where they become associated together as neural ganglia, or form nerve threads connecting the ganglia with rudimentary sense organs. Here we see the first beginnings of this nervous separation which reaches its climax in man.

In the development of the human embryo the same process is observed. All the forms of nervous mechanism, whether afterwards forming parts of the central or epidermal system, have their origin in the ectoderm, and only become separated as the development continues.

The brain takes its rise from the fusion of differentiated ganglia and nervous cells, which pass in the fœtal development through almost identical forms to those which were possessed by creatures at different stages in the zoological tree.

In looking at the embryology of the human nervous system we notice that in man, as in all the higher vertebrates, it originates in a simple medullary tube which separates from the outer germinal layer in the middle line of the sole-shaped embryonic shield. At first this tube lies directly under the horny plate, and the tube joining above the latter forms a completely closed canal.

This gradual embedding of the neural substance within the body, and separation from the primitive epidermal layer, is a process acquired with the progressive differentiation, and the greater protection and potentiality which this secures renders the highest development possible.

The rudimentary brain is a simple multi-ganglionic bulb which by division produces first three and then five vesicles, each of which develops in different degrees as progressively higher types are reached.

Their position in regard to each other also changes until we have the preponderating cerebrum in man, with the subordinate cerebellum and the downward extension of the medulla oblongata. The brain is physiologically and embryologically older than the spinal cord, and in man the cerebrum becomes so large that it covers all the other parts of the brain.

Finally, the brain is enclosed in the skull and the spinal cord in the vertebral column. Twelve pairs of nerves proceed from the brain in connection with the special sense organs, and thirty-one pairs from the spinal cord to the rest of the body, to form connection with the numerous ganglionic centres and their associated group of nerves. Some of them, the sensory nerve fibres, conduct the impressions of the skin inward to the central marrow, while the motor nerve fibres convey the dictates of the will outward to the muscles and other mechanism of the body. The rudiments of the sense organs are at first merely parts of the primary ectodermic layer in which the nerve terminations are expanded, and which on further development are gradually endowed with special functions, as the result of what we may term the division of labour.

Originally of a comparatively homogeneous character, they become endowed with specific functions to perform which the nerve terminations become converted into wonderfully complex organs.

These originate partly from the horny plate forming the embryonic shield and partly from the rudimentary brain and the foremost part of the medullary tube after it has separated from the shield.

The terminal expansion of these nerves corresponds to three stages in the embryonic growth, forming successively the organs which enable man to have impressions of pressure, warmth, and sex; the organs of smell and taste; and, lastly, of sight and hearing, which are correlated in a mysterious way with vibrations received from the luminiferous ether and the air.

The whole of the organs of the body are thus fitly joined together by a complete network of nervous matter, through which the transformed energy developed in the metabolic changes is transmitted to each living cell, and so the due performance of its function in the associated economy is secured.

Further, the controlling influence of the great nervous centre, the brain, is thus provided for and the metabolic equilibrium of the whole system secured.

The Structure and Mechanism of the Nerves.

Having now explained the function of the nervous system and its origin and development it is necessary to consider the nature of the nerve material and its structure and mechanism as exhibited in the different nerves and their arrangement.

We have already seen that the delicate nerve substance of the brain is protected from abrasion and injury by means of a membrane of triple thickness lining the inner surface of the skull.

This triple-layer type of membrane is reproduced in all the external surfaces of the body, such as the skin, and even the internal lining of the mouth and digestive tract. It even extends to the appendages of the skin in the different form of cells, building up the substance of each hair.

The lining membrane of the skull is extended downward over the surface of the spinal cord. The nerve substance is thus completely encased in a triple sheath similar to the covering by an insulating material of an electric cable. The liquid contents of the nerve substance are greater than that of the covering membrane and the liquid cells are always ionised. The cord itself is cylindrical with a spindle-shaped bulb just below where it passes into the vertebral column and another in the region of the loins. The nerve branches proceeding from these are also encased in an extension of the triple membrane. At the top it passes through the medulla oblongata into the brain substance. Although the material in immediate contact with the covering membrane is a comparatively firm mass of nerve substance there is a narrow canal in the axis which passes into the cerebral ventricles above and is filled with a clear fluid, and the nerve substance of the spinal cord is thus placed in direct connection with every part of the complicated brain structure. Three different forms or kinds of tissue are found in nervous matter, viz., nerve cells, nerve fibres, and an enclosing tissue which supports and binds together the nervous elements.

Nerve fibres always consist of the long process of a nerve cell, and in most cases they are associated in bundles and enclosed in a delicate membrane called the primitive sheath. In distribution these nerve bundles become dissociated and ramified into every part of the organs with which they are connected.

The individual cells of which the nerves are composed and which assume in different parts of the system many forms, are not simple tissue-building cells, but those which have been differentiated and sorted out from the others forming the primitive ectodermic layer as specially sensitive to stimulus, or cells which have had their origin in them. Their special sensitiveness makes them more ready to undergo metabolic change, and in the living organism they are broken down and replaced with a greater rapidity than any others which are found in the organism. This is specially the case in the brain where the cell absorption and reproduction is extremely rapid, and this is provided for by about six times the quantity of blood being supplied to the brain than to any other organ of the body in proportion to its weight. This accounts for the great exhaustion produced by excessive mental anxiety or work.

The cause why the nerve cells are more sensitive to stimulation and conduct impressions more readily than other cells is at present unknown to science. We can only surmise, but experiment in cell contents and activity has given conclusive proof that no cell can perform its functions when the contents are not ionised and therefore able to act as electrolytes. This seems to be a function of some of the mineral constituents of the blood, which, when absent, render the cells unable to work, while when restored the action again becomes normal. The presence of ions or electrons are a necessary condition for electric conductivity, whether in solids or liquids, and it appears that if a larger quantity are present in a substance it may become an efficient conductor even when dielectric environment is small, and specially when a low tension is employed as is always the case with neuro-electricity. It is interesting to note that the neural cells are of three kinds depending on the position which they are to occupy in the system. They may be *unipolar*, *bipolar*, or *multipolar*.

The *unipolar* are generally found in ganglia and in the posterior roots of the spinal nerves, and they only give off one axis cylinder process. *Bipolar* cells are generally found in the embryonic stage of unipolar cells, but in some of the lower forms of life they persist permanently in the spinal nerves. *Multipolar* cells abound in those tissues which are undergoing the most rapid change, and hence are found chiefly in the brain and spinal cord and especially in the horns of the grey matter of the latter, where the ganglia are so large as to be almost visible to the naked eye. They assume many forms and develop many processes, but it is seldom more than one is an axon which can be associated with an adjacent neurone. All nerve cells have generally a large clear nucleus. The mechanical arrangement and distribution of the nervous system in relation to the various organs of the body may be compared to a well-designed electrical installation. They resemble in both anatomic structure and physiological function an extensive telegraphic system. The chief station where the neuro-electricity is generated is the brain, and the stimulus which sets the generators in action may be either an exercise of the will or stimulus from without.

The spinal cord or central nervous system, the innumerable ganglionic cells which are connected by branching processes with each other and with numbers of very fine conducting fibres, forms the distributing agency. This is not a fanciful comparison, because it has been conclusively proved by electro-pathologists that nerve stimulation is always associated with electric-like currents which originate in the brain and circulate in the nerve conductors. Further, that the various parts of the body are always in a state of difference in electric potential by means of which currents sufficient to deflect a sensitive galvanometer can be produced. Also, as will be shown hereafter, that areas of abnormal metabolic action can be exploited and mapped out with unerring accuracy.

These nerve currents, acting on the ionised cell contents in the living portion of the body, are, as we shall shortly see, the cause of the metabolic activity, and any interference with these currents, either by reduction of their potential or quantity or loss of conductivity or insulation in the nerve substance, must lead to disturbance of the metabolic equilibrium, a state which is always accompanied by congestion and a rise in the temperature of the blood.

So intimately connected is the relation between neuro-electricity and the metabolic changes which occur within a fully ionised cell, that it has been found possible to start the process of cell division in the ovum of the sea urchin by a simple electro-chemical stimulus, so that the resulting formation of cells, and ultimately of all the tissues and organs follow, as a consequence, quite apart from the means by which this is ordinarily accomplished.

Relation of the Nerves to Cell Activity and Metabolic Change.

Having looked at the mechanism of the nervous system, we must now examine its relation and function in regard to the chemical action which is continuously exhibited in the plasmic contents of every living cell.

While the cells, which form the ultimate structure of all organic bodies, work collectively as an organic whole, they have also an individual function in relation to the particular parts with which they are associated, and in this respect each cell acts as if it was independent of the collective action and forms a separate laboratory in which continuous metabolic and anabolic changes are occurring.

They have all one condition in common, viz., that each living cell is supplied with nutriment and oxygen by the circulation of the blood and the return current carries away the effete material which would otherwise clog and poison the cell plasma. The blood is purified by being brought into direct contact with oxygen in the lungs, where the unnecessary carbonaceous matter is changed into carbon dioxide, and the heat generated keeps up the temperature of the blood in a healthy person at about 98·4° F.

The freshly oxygenated blood passes on to each separate cell, and in each of these a minor consumption of organic matter takes place, which exhausts the oxygen conveyed by the red corpuscles and enables them to absorb the products of combustion. This combustion warms the cell contents independently of the heat of the blood supplied, and then the products pass into the venous circulation.

If from any cause the warmed cell contents are not removed and passed into the circulation, or they are not kept constant by the enswathing lymph, the temperature of the individual cell rises and causes local inflammation. When this rise in temperature occurs over a large area and it is apt to become cumulative, the temperature of the blood is even raised, because the heated products of combustion are not being removed and this may have serious results.

Normal blood temperature is always associated with health, and a rise in temperature is the sure indication of disease.

In addition to the red corpuscles there are always associated with them in the blood a series of white corpuscles which are essentially different in character. They are usually in the proportion of one to 700 of the red. These are called phagocytes because one of their functions is to absorb any foreign organisms, such as disease germs, and by assimilation destroy them before they become too numerous. They are the scavengers of the blood. A rise in the temperature of the blood at once renders these phagocytes sluggish, and in proportion to the rise, incapable of performing their proper function while it renders the disease germs more active and their propagation more rapid. It acts also in a deleterious manner on the red corpuscles, and thus hinders the removal of effete matter, and so the cell contents become poisoned, an action which also becomes cumulative. The reduction of inflammation at once restores the advantage to the white and red corpuscles, and hinders the activity and propagation of the inimical bacteria, and lessens the abnormal production of substances upon which they thrive the best.

The materials of which a cell and its contents are composed are all found in the inorganic world, but the living cell substance possesses chemical compounds which find analogues nowhere in inorganic nature. The typical cell content is *protoplasm*, an exceedingly complex body, which has never been analysed except when it has ceased to live, but which is composed of proteids and proteid-compounds.

From this by metabolic action every organ of the body is derived and supplied with the necessary carbohydrates, fats, sugars, and other organic substances which are required for their structure or use. Water and inorganic salts are always present and essential. The chemical action takes place within the cell and the products of decomposition are given off through the cell membrane into the circulation.

Along with metabolism there is always inseparably associated a transformation of energy which has as a result the activities of the organism, more especially mechanical motion, heat, light and electricity. If any cell or group of cells is isolated from nervous influence and control the whole of its activities cease in a short time. Not immediately, for each cell always contains a store of potential energy which by its action is changed into the kinetic form. This is especially the case where the isolated region is well supplied with ganglia, and can draw upon these when the main supply is cut off.

The thermic reactions which occur in all normal metabolic changes are the result of alterations in the molecular structure of the substances which are in process of fluctuation, and the temperature generated is the difference between the exo- and endo-thermic results of the change, the temperature rising with the excess of the former over the latter. This is a definite amount which can be calculated when the exact nature of the change is known. When, however, the cell is generating ions, its reactions are atomic and not molecular, as the ions can only be obtained at the expense of atomic disintegration when the heat liberated is enormously greater than that arising from molecular change even if the results are all exo-thermic. It is found roughly to be about one million times greater than would be generated by the combustion of the same weight of coal, a source of energy within the organism only recently discovered as the result of the metabolic activities of the cell, and which, when fully explored, may yield surprising results.

The proteids and their compounds are comparatively stable substances, and never undergo spontaneous decomposition so long as they are protected from outside influences. In the cell, however, they are wonderfully labile, and continually undergoing apparently spontaneous decomposition and forming new combinations which, from their association with a living cell, are termed *biogens*, and these in their turn, by a series of secondary chemical processes, the reactions, which are at present obscure, result not only in the formation of all the tissues of the body, bone, muscle and nerve, but also in the formation of protoplasm out of which they can be reproduced again in a continuous circle so long as a supply of food and neural energy is furnished to the cell.

The association of matter and energy will always probably present difficulties insoluble by the mind, but the consideration of these phenomena seem to throw light on the nature of nervous action, and to offer some possible explanation of the reason why nerve substance can respond to stimulus.

The nerves themselves are composed of biogenous material which is in a constant state of flux, but the cells themselves, apart from any outside influence and supplied with a constant and sufficient portion of nutriment, are in a state of metabolic equilibrium. An outward influence such as the stimulus of touch, heat or light, which through its appropriate medium will accelerate or retard chemical change, at once disturbs this equilibrium, and the disturbance, like a strain in the ether, which is the cause of light, will be propagated from cell to cell through all the sensitive nerve tract. If this occurs as the result of a touch it is propagated to the brain, and reflex action disturbs the changing biogens in the automatic centres and retrocession of the part touched follows. Every time a nerve transmits a message as a consequence of the disturbance of the metabolic equilibrium, the process is arrested and the nerve cells undergo partial destruction. To restore this as quickly as possible they need a constant supply of nourishment and special nervous control. For the latter they are supplied with a set of nerves called *nervi nervorum* (nerves of the nerves), and for the former a special set of blood vessels which ramify round them in microscopic networks.

The cells in the nerve substance possess the capacity to receive and retain *specific impressions* so that they, when thus differentiated, only transmit one form of message whatever may be the nature of the stimulus. Thus the same blow on the head which conveys by one set of nerves the sensation of pain will, if the auditory or optic nerves be stimulated by the blow, cause the sensation of sound in the one and light in the other, so that the person struck hears the blow and sees stars or a flash of light. An electric stimulus would have the same result as the blow on the several nerves although the stimulus is of a totally different kind.

Nerve matter is thus a specially prepared material, and its cells, differentiated from all others by selection in the early layers of the embryo where they have been subjected to special environment in which they have been able to acquire increased irritability and can transmit it to their offspring. In this connection it must be remembered that every unit of a dividing cell carries with it a portion of the original cell plasma, which constitutes a cell immortality and a congenital unity for every life form.

Neuro-Chemistry and Metabolism dependent upon Neuro-Electricity.

The living cell has already been spoken of as a laboratory, more or less specialised, in which constant chemical reactions are taking place, resulting in the formation of biogens, and these again redistributing themselves in new and more complicated compounds, which are again broken up by the metabolic changes necessary for the requirements of the organism.

Within the cell, the base upon which the whole of the chemical reactions rest, is the substance *protoplasm*.

This substance has the form of a labile jelly or slime of the consistence of a liquid starch paste or a strong solution of albumin and never becomes solid while in an active condition. It belongs to a class of bodies known as *colloids*, and the chemistry of life organisms is the chemistry of the colloids. These bodies will not diffuse through animal membranes and are distinguished by the size of their constituent parts and their high molecular weight. While that of hydrogen is 2 and that of the heaviest salt metal not more than 300, that of starch is about 100 times greater. True colloids are never conductors of electricity and were classed by Graham, who was the first chemist to investigate their properties, as of two kinds, *sols* and *gels*, according to their more or less liquid consistency. Protoplasm has the nature of a sol.

Associated in the cell contents there is another class of substances which have exactly opposite qualities to the colloids—Graham termed them *crystalloids*. They readily pass through animal or vegetable membranes and can be separated out in a solid crystalline state. They are all conductors of electricity and have a comparatively small molecular weight. Both are absolutely necessary to the performance of the vital functions in a cell—the one giving the stabilising condition necessary for the permanence of the structure, and the other the means by which communication can be maintained with the other parts of the collective organism, the introduction of nourishment, and the removal of waste. It was formerly thought that these two classes of substance had no intermediate forms and the relation in which they stood to each other in the cell plasma quite distinct and without any transition from one to the other. When in a passive condition this is doubtless true and marks the difference in which they are associated with their aqueous menstruum—the molecules of the colloids being in a suspended condition and not undergoing mutual interchange of their respective constituents, while the crystalloids are in true solution and a constant atomic change occurring. The form of a colloid is that of an emulsion, of a crystalloid of an infusion. There are, however, intermediate forms, and the physical properties of emulsion and suspension colloids are easily distinguished by the nature of their electrical charge. The organic colloids and metals of the platinum group always carry a negative charge, while the hydroxide solutions of iron, aluminium, etc., always a positive charge. The nature of the charge in these never varies, and colloids with the same electrical charge never precipitate each other. In emulsion colloids, however, the sign is easily changed, and it is these which form the most important part of protoplasm. It depends upon the chemical condition of the medium of solution which charge is taken. If the reaction is alkaline, the charge is always negative—if acid, positive. The electric condition of the ions, however, cannot alter the colloid state, but can determine the nature and rate of the changes which are in progress.

Further, it is now found that in the metabolic changes within the organism there is transition between the respective forms, typical colloids such as egg-albumin being step by step transferred into soluble substances where these proteins are split up by the action of digestive ferments.

The first products, the proteoses, are truly colloid and only slightly removed from the original protein. The peptones which are the next products of decomposition, are less colloidal, although not crystallisable. Their molecular weight is under 1,000 and they are electrolytes, showing that there is atomic dissociation occurring within the substance. Soap solutions are of the same order and these along with the peptones, are widely spread constituents of cell-plasma.

There appears to be evidence that in the cell plasma there are substances which are of even higher complexity than the proteids, and which are in more unstable equilibrium, and these bodies have specific functions in regard to special changes and organs. They are termed *hormones*. The formation of these products in certain secreting glands, and which are transfused directly into the circulation of the blood, is entirely dependent upon the due supply of neuro-electricity to the cells forming the glands. If this is not supplied hormones are not formed, and in their absence as stimulants in the special cells in other parts of the body which they excite to activity, healthy life becomes impossible.

The application of modern views in regard to the nature of solution as applicable to the study of biology, marked a distinct advance towards our knowledge of the *modus operandi* of the cause of changes in the living cell, and therefore furnished a clue to the possible solution of metabolic action.

Physicists have demonstrated that matter is composed of separate parts. In the order of their complexity they are termed molecules, atoms, and electrons.

Molecules in which the distinctive properties of the various kinds of matter inhere, such as water, salt, or sugar—these molecules are themselves composed of smaller molecules or their constituent atoms. Thus water is formed from the union of hydrogen and oxygen. These atoms are themselves built up of still smaller bodies termed electrons, and these have had their mass determined as 1,000 times less than the mass of the hydrogen atom. They are of two kinds, negative and positive. The negative ions which possess this mass have been isolated, but the positive ions have never been isolated, but are supposed to be larger and to have a mass equal to the hydrogen molecule.

The old idea of the nature of solution was that the salt when dissolved consisted in the separation of the constituent molecules and their diffusion through the whole volume of the water, so that when the water became saturated these molecules were equally distributed by a process of diffusion throughout every part. It is now held that this view is incorrect and that when a salt is dissolved in water its constituent molecules undergo, to a greater or less extent, atomic as well as molecular dissociation, so that a portion at least of the electrons become free and are diffused through the water as *ions*. These free ions are the cause of the conductivity in the electrolyte, because they carry the current and deliver the conducted charge at the respective poles.

In any solution the degree of this dissociation depends on the nature of the salt, the temperature of the solution, and the degree or strength of the solution. Strong acids and alkalies when diluted down to 0·001 of one gram in one litre of water are entirely broken up into ions and cease to exist as salts. From a biological point of view this is most important and furnishes a clue to many mysteries. So important is the part played by these ions in any chemical change within the electrolyte that the reactions may be considered as taking place between the ions.

In many cases there is strong evidence to show that the ions do not act singly but in groups. This formation of complex ions is specially important in metabolic changes. Under certain conditions living cells which have become depleted of ions can even form new ions from non-ionic materials, and thus under the influence of a sufficient stimulus become rejuvenated with all their functions restored.

This knowledge when applied to the chemical changes within the living cell is of the utmost importance and of wonderful suggestiveness, and is now being made the subject of many and careful investigations.

It is possible to study them better in vegetable than in animal cells, not only because they are larger and more distinct, but because in the roots of plants we have the direct transference of the salts from the inorganic into the organic cell-contents.

The salts dissolved from the soil are taken up by the roots as a very weak solution containing a mixture of sodium, potassium, lime, magnesia and iron, in association with hydrochloric, sulphuric and phosphoric acids. Also compound salts such as those of ammonia. These are the mineral constituents, which the plant cell, deriving its energy from sunlight acting on the chlorophyll, builds up into the complex protoplasm along with the carbon derived from the carbonic acid in the air. The protoplasm in the plant cell is absolutely undistinguishable from that in the animal cell.

The most singular fact is that the dissolved salts do not themselves pass into the cell plasma, but only their ions, and these disappear very rapidly in the reactions and have to be continually replaced from without and no cell activity is possible without their presence. They are only present in the active cell-contents and not in the formed matter which is the result of the metabolism. That it is only the ions and not the salt molecules as such that are in the plasma has been decisively proved. Thus in the living cell-contents we cannot find a trace of potassium in the well-known reaction with platinum chloride. The smallest trace of this salt yields a yellow deposit, but not a trace can be obtained in the living cells. In the ash the reaction is certain. It seems as if in the living cell potassium salts are transformed into ionic compounds and that they act in the living cell not as salts, but as separate or groups of ions and that physiological activities vary according to changing electrical conditions depending on whether the positive or negative charge prevails.

There are thus revealed in living matter subtle phenomena of which at present we know little. We have already seen that every metabolic change is accompanied by a transformation and liberation of energy, and in all living cells, especially in the animal organism, one of these forms is always electrical.

Every nutritional change in a cell or the tissues, every secretion of a gland, every contraction of a muscle are associated with electrical phenomena which can be demonstrated by suitable means with a sensitive galvanometer.

Muscular tissue is in some animals so modified as to give charges of great intensity as in the electric organs of the gymnotus, the torpedo, and the ray. Even the glands of the skin may give a shock as in the mud fish of the Nile.

Antecedent to every muscular contraction there is always a change in electrical condition, and the automatic action and working of the heart is absolutely dependent on the presence of electrolytes in the cell-contents. Without ions in the living substance of the cell and in the fluid surrounding it, it cannot respond to the action of the forces operating upon it. In this respect the ions of a potassium salt seem to be more potent than others.

If an animal's heart is isolated, as stated by Professor Moore, and fluid containing a solution of foodstuff resembling blood be passed through it, the muscular structure will at once cease to act and the heart stop beating.

If, however, a solution of common salt be used the heart will continue to act for some time, but finally ceases when the solution has washed out the potassium salts from the muscular structure of the heart. If, however, a definite proportion of potassium and calcium salts are added to the solution so as to restore the ions in the cells and the solution is passed through a freshly-isolated heart, it will continue to work for hours or even days.

Living nerves also show electrical changes similar to those found in the muscles. Their structure is more sensitive and the cells usually more highly ionised so that they are good conductors of electricity. Although far inferior to metallic conductors the current in them can be transmitted with a velocity of at least 200 feet per second.

There are, however, conditions which indicate that the electric conductivity and other characteristics are different in the nerve to ordinary electrical manifestation in a live circuit and that it is a special form which may be termed *neuro-electricity*. Thus when a nerve fibre is stimulated at any point it immediately acts not only as a conductor, but at the point stimulated there is a change generated and a current transmitted in both directions apparently as the result of accumulated energy in the substance of the nerve. It acts like a continuous current circuit where the effects required are obtained by breaking the circuit and not calling it into play. In a nerve ganglia the effect is transmitted in every direction in which it is linked up.

This constant dependence of all metabolic activity upon the neural currents transmitted to every organ and its individual cells shows conclusively how the healthy action of every part of the body is absolutely dependent on the maintenance of these nervous conductors in the highest state of efficiency so as to prevent loss either in quantity or potential. It also reveals why an inflammatory condition must arise when this is interfered with, and its suppression follow as a result whenever the normal electrical conditions are restored.

PART II

ELECTRO-PATHOLOGY

AND

THERAPEUTICS

ELECTRO-PHYSIOLOGICAL RESEARCH.

By A. E. BAINES.

SYNOPSIS

PART II

ELECTRO-PHYSIOLOGICAL RESEARCH.

THE HISTORY OF ELECTRO-PHYSIOLOGY AND THERAPEUTICS FROM 1773 A SERIES OF CONTRADICTIONS—CAUSES WHICH HAVE CONTRIBUTED TO ERROR—THREE FACTORS WHICH HAVE NOT BEEN TAKEN INTO CONSIDERATION—CHEMICAL GENERATION OF NERVE FORCE, CAPACITY OF THE BODY AND THE CAPACITY OF LIQUIDS AND MOIST SUBSTANCES—STATICAL GENERATION OF ELECTRICITY—THE STORAGE CELLS OF THE BODY.

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PART II

ELECTRO-PATHOLOGY AND THERAPEUTICS

Electro-Physiological Research.

While one cannot but admire those eminent men who, from the year 1773 until the present day, have laboured in the field of electro-physiology there is no course open to me but to question many of the results obtained by them, and to believe that the conclusions at which they arrived are, in the main, erroneous and misleading.

The history of electro-physiology and electro-therapeutics, to which the earlier experiments led, places upon record a series of contradictions instead of a mass of valuable and confirmatory data.

It would not serve any useful purpose to enter into details. Many of the experiments were of the greatest importance, but owing to the non-discovery of three fundamental factors—factors which it has been given to me, at all events partially, to determine—it was unfortunately impossible to separate the grain from the chaff.

Let us briefly examine what took place between 1773 and 1873—one hundred years.

In 1773 Galvani advanced certain theories. These were contradicted by Volta. In 1779 Humboldt's experiments went to show that the theories of both these gentlemen were untenable. Some twenty years later Aldini—a nephew of Galvani—published results demonstrating the existence of what is known as animal electricity, but he was overshadowed by Volta; while in 1827 M. Nobili confirmed the researches of Galvani. Sometime afterwards Matteucci turned his attention to the same subject, but it was reserved for Du Bois-Reymond to investigate more fully the electric properties of the nerves and muscles, to negative the conclusions of Volta, and to hand down to posterity many truths and a new series of errors.

Some half a century later Dr. C. B. Radcliffe took a radically different view of animal electricity, and made a wider departure from fact than any of his predecessors, while in the same year Professor Trowbridge, of Harvard College, America, cast grave doubts upon the value of the researches of Du Bois-Reymond, and provided us with fresh food for anxious thought.

Since that time some progress has been made, but, the same erroneous methods of experiment have been persisted in, and we are, therefore, still far from an understanding of the natural human neuro-electrical* system and the laws which govern it.

The question necessarily arises, "Why is this so?" How is it that these great men of science have not only been unable to agree but have really discovered little of service to humanity? The reasons are not far to seek.

In the first place they were not, any of them, trained submarine cable electricians whose business it is to acquaint themselves with the conditions under which tests of such extreme delicacy and difficulty must be conducted. They were men of extraordinary attainments. They knew many things, and in many ways left their mark upon the world. But they were not, I repeat, specially trained, and for this branch of research a specialist is imperatively called for.

And here it may be interesting to shortly relate in what

* In this treatise, when I speak of the nerve current I shall term it "neuro-electricity."

manner I was led to commence the experiments which have culminated in my part of this treatise.

Many years ago I was detailed by my employers, the Eastern Telegraph Company, to assist Mr. Finlay, of the Cape Observatory, in correcting longitudinal data by means of time signals by cable between Durban and, I think, Aden. It was necessary to send and receive signals while listening to the loud ticking of a clock specially made for astronomical work. The signal had to be sent to the exact tick and when received recorded at the exact tick, and Mr. Finlay showed me the importance of ascertaining my personal coefficient of error (his own being, if I remember rightly, $\frac{3}{10}$ths of a second) in order that allowance might be made for it. Sometime afterwards, while engaged in cable testing, I noticed a deflection upon the scale of the Astatic galvanometer for which I could not account, and upon investigation found the disturbing influence to proceed from my own body. I, in fact, wrote an article in *The Electrical Engineer* in May, 1885, entitled "The Human Body as a Disturbing Element in Electrical Testing," from which I quote the following: "I am of opinion that in every case where use is made of an unshunted galvanometer of great sensibility the operator should be careful to connect himself during the test with an earth plate, instead of, as is usual, standing upon some insulating substance. This conclusion was forced upon me some years ago. I was in the ordinary course of business comparing a 10-microfarad condenser with one of 1 micro capacity by Sir William Thomson's" (afterward Lord Kelvin) "method, employing a very sensitive Astatic galvanometer and two platinum-silver resistances, arranged so that a difference of one ohm resistance gave me a difference of ·001 microfarad capacity. The insulation of the battery and other apparatus was absolutely perfect; I used a current of very low electromotive force, in order to avoid heating, and took all the precautions which are laid down by others and which our own experience suggests. The 10-micro condenser varied in the most inexplicable manner between 8·929 and 8·931 micros. In all there might have been a hundred readings taken, each time, or almost each time, with a different result, with a discrepancy of about ·001 micro, and it was not until I observed a slight galvanometric deflection while the battery circuit was open that the probable cause suggested itself to me. During the course of some experiments I afterwards made under different conditions to verify the idea then formed, I stood as closely as possible to the galvanometer circuit, and upon being charged with 20 volts produced a slight *inverse* deflection upon the galvanometer; when the circuit was opened a slight *direct* deflection was noticeable. After having connected myself with an earth of low resistance the phenomenon ceased to manifest itself and I succeeded in getting a balance."

My association with Mr. Finlay was fortunate. Had it not been for that I should, in all probability, have dismissed the vagaries of the galvanometer as being due to leakage, and, so far as I am concerned, the experiments might never have been made.

That, however, is a matter to which we need not attach undue weight. The causes of the confusion, the sources of the error of the past lie, in the main, in three factors which have never been taken into consideration, and which, I venture to suggest, have not hitherto been discovered, although I pointed them out long ago. Those three factors are:—

1. The chemical generation of nerve force in the human body.
2. The presence in that body of great conductive and inductive capacity; and

3. The conductive and inductive capacity of every liquid and every moist substance or object.

Let us see how these factors come into play as sources of error.

That the human body generates electricity statically—by muscular movement—is well known, but this charge can be dissipated almost instantly by placing the body in contact with an earth plate of low resistance. That it possesses great conductive and electro-static capacity is also known, because when perfectly insulated the body can be charged to a very high potential. That it has inductive capacity also is not so well understood.

So far as capacity is concerned, and disregarding for the moment the chemical and statical generation of electricity, we may liken the body to a collection of storage cells, which are liable to become more or less highly charged, or to have their charge altered by any direct or passing current or exciting influence.

Now these storage cells cannot, if they depend for their charge upon some outside current as the exciting influence, be in a constant state of tension because the outside current is not always flowing either to charge them directly or by passing in the immediate vicinity of the body. We must then depend upon muscular movement for the charge, and if we find, as we do find, that movement of any kind exercises only a momentary effect upon the electromotive force; and that, within limits, electromotive force continues to be produced even when the body is absolutely motionless, we must look further for the source of energy.

Chemical Generation of Nerve Force.

This is one of the reasons why we should accept the theory of chemical generation of nerve force. There is no reason, so far as I am aware, why we should not, as we are quite familiar with the fact that we can generate electric current by chemical action, as in the case of primary batteries. There are several grounds for the belief that nerve energy and electricity are not identical, but it may be sufficient to give one.

In anæmia, as well as in other affections, the potential and therefore the quantity of neuro-electricity (R remaining constant) become subnormal. The application of a weak continuous galvanic current to the body will, for the time being, restore the potential to normal, but inasmuch as the charge so administered begins to escape from the body the moment disconnection of the battery is made and disappears entirely in an hour or so, it appears to me to be proved conclusively that the ganglion cells are incapable of retaining it: that it is, in fact, a form of energy differing from that supplied by Nature to man. It is impossible to absolutely drain the body of neuro-electricity by placing it in contact with an earth plate of infinitesimal resistance, and it cannot be brought down to the potential of the earth. Again, all the nerve currents are downwards from the brain to the solar plexus (so far as all my results are concerned), and the distinct falling off in generation when the blood is deficient in iron or the air in oxygen is at least corroborative. I advance the opinion with some diffidence, but I cannot but place the source of generation in the brain itself.

We will now take the factors before-mentioned *seriatim*, but before doing so it would be well to mention that in the majority of tests, upon which the conclusions to be given hereafter are based, a Kelvin astatic mirror galvanometer of a resistance of 88,000 B.O.T. ohms at 15° C. and perfect insulation was used.

The electrodes I will describe later.

Now it is quite clear that if neuro-electricity is constantly generated in the body it must be as constantly given off, otherwise the electrical pressure would become unbearable. The insulator of the body is the skin, and it is not an insulator of very high resistance. Nor is its resistance uniform any more than the generation of neuro-electricity is uniform in all individuals. *Sign*, *electromotive force* and *current* vary with the person as much as height, weight, and anthropometric measurements vary.

If nerve energy were visible we should probably see every human being—one might almost say every living thing—surrounded by an aura or magneto-electrical field extending some distance from the body and gradually fading into space.

We must, however, realise that the rapidity with which that neuro-electricity can pass to earth must depend upon the manner in which the body is insulated from the earth by dielectrics other than the skin. For example, the insulation of a carpeted room with the windows and doors closed would be infinitely higher than if the body were exposed to the open air, or in contact with damp earth, or with the hands touching some metallic body implanted in the earth. You may, in fact, conceive many conditions in which the insulation of the body could be increased or impaired.

That being so, it is evident that while the generation of neuro-electricity in the body may be constant, the dissipation of it cannot be so by reason of the varying conditions of exterior conductivity.

Another important point to remember is that the sign of current in individuals is not always the same. Taking the right hand (as a whole) as one terminal and the left hand as another terminal of the body, one person may be negative and another positive. In this respect the body resembles a galvanic cell whose terminals, electromotive force and internal resistance are unknown until tested and ascertained.

The bearing of all this upon error will soon become apparent. Let us imagine ourselves in a laboratory, the floor and walls of which oppose considerable resistance to the escape of electricity, and let there be two people conducting, say, the experiments of Professor Trowbridge. We, however, will take the precaution of testing them for personal neuro-electricities and—to quote figures obtained in actual practice—say that A. gave a deflection of 100 millimetres positive and B. of 200 millimetres negative upon the scale of the galvanometer I have mentioned. After about half an hour the air of the laboratory would become charged by reason of the neuro-electricity escaping from the persons of A. and B., and as 100 positive − 200 negative = 100 negative the air must become negatively charged, increasing in tension or pressure with time or varying with any alteration of the conditions of contact.

In this we have one of the sources of error. The tension and sign of the atmosphere in the testing room have always been unknown quantities; an undetermined x.

Personal Capacity.

I have not of recent years taken any actual measurements in units, but the mean of a former series of tests gave over 3 microfarads as the average conductive capacity of the body. Now if B. (= 200 millimetres negative) touched A. (100 millimetres positive) A. would become 100 millimetres negative so long as he remained shut up with B., or failing direct contact between the two the air of the room would so charge A. as certainly as water would find its level. Inductive capacity introduces another and equally perplexing source of confusion, as a flash of lightning, a powerful earth current, the proximity of a charging station or of an electric railway would not only affect the persons experimenting, but also the subject of experiment, although the galvanometer itself might not be perceptibly influenced.

THE CAPACITY OF LIQUIDS AND MOIST SUBSTANCES.

But that is not all. Physiologists entirely overlooking conductive and inductive capacity have invariably used what they call non-polarisable electrodes, or contacts to which the objects under examination are connected for the purpose of conveying the currents of electricity supposedly emanating from them to the coils of the recording instrument. These electrodes were and are moistened with some liquid, and as all moist substances absorb electricity, as a sponge absorbs water to the limit of its capacity, it follows that unless each electrode is exactly of the same area and density, there will be a controlling electromotive force from the larger of the two. It also follows that if one electrode has a thousandth part more moisture than the other, there may be an opposing electromotive force, and furthermore—disregarding minor details—those electromotive forces would be liable to variation from time to time by—

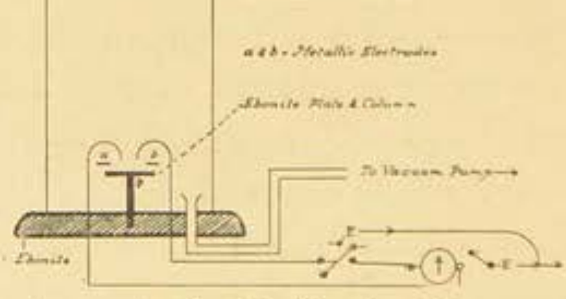
1. The number of persons present in the laboratory; the length of time they remained there, and their respective neuro-electrical signs and electromotive forces.
2. The nature of the liquid or liquids employed.
3. The degree of absorption.
4. The area of the electrodes; and
5. The amount of moisture present in the object or subject under examination.

Let us suppose that our galvanometer scale has a range of 300 millimetres each side of zero, and that A. and B. (as before) have conducted a number of experiments—reproducing Professor Trowbridge's conditions—with a piece of muscle in a moist condition, and have obtained certain data. A. and B. would always get the same results, because the muscle would invariably have a charge equal to 100 millimetres negative.

Two other persons C. and D. question the accuracy of the published results of A. and B., and proceed to verify or disprove them. C. let us say = 300 millimetres positive, and D. 150 millimetres negative. The resultant electromotive force and sign are 150 millimetres positive; the muscle is differently charged and the results are, and must be, contradictory. In the same manner E. and F. may prove both A. and B., and C. and D., to have been hopelessly incompetent, and in their turn be subjected to similar criticism at the hands of scientists who follow them.

A way out of the difficulty would be to place any dead substance or object to be tested in a vacuum, earth it in that vacuum, and then switch off the earth and put it in the galvanometer circuit, while still in the vacuum. Another and more simple method would involve placing everyone present (except a living subject) in contact with a good earth plate during the continuance of the tests and earthing the object under examination from time to time. The results given by such tests would, I venture to think, be both valuable and instructive.

I have designed the following apparatus with a view to affording additional proof of my statements in regard to dead material, the connections being shown partly in elevation and partly in plan.



Apparatus for Testing in a Vacuum.

I venture to think that any piece of muscle or tissue, or in fact, anything from which life has departed will not, if tested by this method, yield any deflection whatsoever after the earth current has been allowed for, and if that is so we may cease to pay any regard to data so far obtained from supposed residual currents.

As a great deal which does not happen to be true has been written about non-polarisable electrodes (wet and dry) by a number of physiologists, it may be well at this juncture to give an account of a few experiments which were carried out over and over again with the object of exploding some favourite theories.

I found that when two wires of equal gauge and length, soldered to two steel needles of exactly the same gauge and length, were connected to the terminals of the galvanometer, and the needles were inserted in various objects and liquids, certain deflections were observed: deflections which were not momentary, but more or less constant.

These deflections are explained by physiologists as being due to galvanic action.

There are two theories, *i.e.*,—

1. Two metals—that is to say, one needle being electrically positive to the other—in one solution, or
2. One metal in two solutions.

It will, however, be only necessary to consider the first seriously, inasmuch as there cannot be two different fluids in distilled water, while the most careful analysis has failed to reveal the presence of two solutions in the juices of fruits and vegetables. Nor can the first hypothesis be sustained if only for the reason that the sign of the deflection obtained is not altered by the reversal of the needles upon the terminals of the galvanometer.

In the case of liquids such as distilled water, the deflection must be of the same sign, and that sign is, and must be, governed by the sign of the electricity with which the air of the testing room is, for the time being, charged.

As I have before remarked it is owing to this fact and to the further important truth that all fluids and moist objects possess conductive and inductive capacity that the results obtained by physiologists have so materially conflicted.

To give an example, let us suppose that the air of the testing room is positively charged. If we cut an inch off the wire connected to the left (say negative) terminal of the galvanometer, we have in that wire—other things being equal—a path of least resistance, and if we fill a vessel with distilled water and insert the two needles in it the current due to the very slight charge imparted to the water during the act of pouring will of course appear to be *negative.* But if the water is allowed to remain in the vessel for sufficient time—say, half an hour—to receive its full charge, the current will no longer travel through the path of least resistance and will give a *positive* deflection. If, however, the water be then thrown away and the vessel refilled with distilled water which has not been exposed to the air the deflection will again be *negative.* This experiment has been repeated very many times with the same result.

So long as an actual galvanic or voltaic cell is not created by the use of two dissimilar metals and a solution to set up chemical action, the same phenomenon is observable in the case of all lifeless moist objects ; that is to say, when the two wires are of equal length and resistance, the deflections which occur are always ascribable to charge imparted by some source or vehicle of energy to the article under examination.

But when under the same conditions we test anything in which there is life, we have different factors to deal with. Fruits and vegetables, for example, are, when in a sound state, storage cells, charged by the earth and the air. All fruits have their negative terminal at the stalk end, and all vegetables at the root. To effectually disprove the theory of two metals in one solution or the more untenable hypothesis of one metal in two solutions is by no means difficult.

In this experiment let us suppose we are using two wires of exactly equal length soldered to two steel needles as before, and that the subject under examination is an apple. In order to settle which is the positive and which the negative side of the scale we will first connect the positive or carbon terminal of a dry cell to the right-hand terminal of the galvanometer, and the negative or zinc terminal of the cell to the left terminal of the recording instrument. The resultant deflection is to the right of zero and we may therefore call the right side of the scale from zero positive, and the left side from zero negative.

Now if we insert the needle connected to the right terminal of the galvanometer in the stalk of the apple and the other needle in the flower end, we get a constant *negative* deflection. Let us admit for the sake of argument that this deflection is due to galvanic or chemical action. If that is so then, *so long as we do not alter the connections and reasoning upon the hypothesis that the right needle is electrically negative to the left needle and that chemical action is set up by their contact with the malic acid of the apple, the deflection must continue to be negative when the fruit is reversed, and the right needle is inserted in the flower end, and the left needle in the stalk end.* Also the signs of both deflections must be reversed if we reverse the wires upon the terminals of the galvanometer.

But it is not so—nothing of the kind ever occurs—cannot occur. Every fruit will give a *constant negative* deflection when the right-hand needle is inserted in the stalk end, and a *constant positive* deflection when it is inserted in the flower end; while every vegetable, plant, tree, and leaf, grown in the earth will yield a constant negative deflection when the right-hand needle is connected with the root, or stalk, or vein, and *vice versâ*. The wires may be changed (reversed) upon the terminals of the galvanometer as often as desired. There will be no difference whatever in the phenomena observed. In the case of pot-grown plants and fruits, however, read positive for negative, and *vice versâ*.

If, however, diffusion takes place by reason of injury or decay, and the fruit, vegetable, plant, tree or leaf, becomes rotten, then no *reversal* of sign will be obtained; the sign will be that of the air of the testing room.

In order to prove this beyond any possibility of doubt we conducted numberless experiments with moist inanimate objects and in no instance succeeded in getting a reversal of sign. We, for example, placed a double cardboard box in water for one hour, until it was thoroughly soaked, and having ascertained that the air of the testing room was *positively* charged, connected it to the galvanometer in the manner I have described, and obtained a constant *positive* deflection. Repeated reversals of the box did not produce any alteration of sign, which of course remained positive, and it would continue to do so while the sign of the air of the room continued to be positive or until the box became dry.

We then took a double strip of green baize which had been well soaked, a rotten banana, a piece of meat, a piece of fish, etc., etc., and obtained positive deflections from all. Without wiping the needle we then put the right-hand needle in the root end, and the left-hand needle in the foliage end of a sound onion, and got a constant *negative* deflection. This was left for ten minutes, when we reversed the onion, leaving the other connections unaltered, and the deflection became strongly positive.

To make assurance doubly sure we afterwards put all the above objects to earth, opened the doors and windows of the testing room and, absenting ourselves, introduced into the room two persons whom I had tested and found to be negative. They repeated, under my directions, all the tests with the cardboard box, the baize, the banana, the meat, and fish, and in every case got a *negative* deflection.

Unsatisfactory Data.

If my conclusions are accepted we can no longer be surprised at the unsatisfactory condition in which we find the science of electro-therapeutics. A necessary preliminary to curative treatment is knowledge of the human electrical system—the generator or generators of nerve force, the conductors and dielectrics, the condensers and their capacity, and what is of paramount importance, the influence of disease upon any or all of them. Until that knowledge is acquired treatment cannot be said to rest upon a scientific basis, and must be to a certain extent empirical. I do not of course include the surgical uses of electricity of high potential, but I do most emphatically refer to high frequency, except as a species of electro-massage—to local and general faradisation, to central and local galvanisation and the rest of it. I also venture the opinion that we know next to nothing of the electro-pathology of disease, that we have no method of electro-diagnosis worthy of the name, and that by reason of the errors of the past and the consequent unreliability of the data already obtained we should lose little or nothing if we forgot everything we had learned, and made a fresh start under improved conditions of enlightenment.

Electro-Diagnosis.

Apart from curative treatment a really scientific method of diagnosing disease, a method in which instruments of extreme precision could be employed, and individual opinion, with its proneness to error, eliminated, would be a step in advance, and must in time make us familiar with the electro-pathological features of each and every disorder.

It cannot be denied that at present there is no absolutely correct method of diagnosis. In their earliest stages there are many diseases which resemble each other too closely for the thermometer or the stethoscope to be useful, while the origin of other maladies such as cancer, functional paralysis, epilepsy, and exophthalmic goitre, etc., is enveloped in almost as much mystery to-day as it was two hundred years ago.

I will endeavour to describe and illustrate a new method of diagnosis and research; a method which in skilled hands cannot fail to yield accurate results.

No battery power must be employed. If the tension is high or the quantity of the power large, the natural nerve current will be swamped, the ganglion cells abnormally and unnaturally charged, and the nervous system generally, for the time being, totally changed. If the tension and quantity are low, opposing electromotive forces will introduce confusion and error, and render the tests useless.

We have in the body a generator of neuro-electricity, a large number of insulated conductors, and a series of storage cells or condensers (which, in all probability, are the ganglion cells), and an outer insulator, a comparatively poor insulator, in the skin.

Let us call the electromotive force "E" and assume it to be constant—which, within limits, it is.

"C" represents the current of nerve-energy flowing through any part of the body, and "R" the resistance of the conductors.

Now "R" varies inversely as the sectional area of the conductor, and as the conductors of the body differ in area it follows that "R," and therefore "C," must be variable.

By Ohm's law we have

$$C = \frac{E}{R}$$

That is to say, the current flowing through any part is equal to the electromotive force divided by the resistance of the circuit through which it flows.

Now while the conductors are insulated they are only insulated sufficiently to maintain in them or upon them nerve energy at a certain pressure, and as the generation of neuro-electricity is constant they as constantly give it off through the insulating covering and thence through the skin to the air, so that if we, for purpose of argument, assume that the sectional area of the conductors is not the same in any *three* parts of the body, we should not get the same deflection from any three different parts of the body. I will not pledge myself to an exact number of parts, but theoretically my contention is, in the main, correct, and it has been amply borne out in practice.

But for the purposes of diagnosis it is unnecessary for the experienced observer to enter into mathematical calculations. It is obvious that the higher the resistance the smaller the current deflection and *vice versâ*.

Upon the scale of an astatic mirror galvanometer, the *quantity* of the current is sufficiently indicated by the *rapidity* of the deflection.

Now disease does one of at least four things, *i.e.* :—

1. It alters the resistance of one or more conductors in the part or parts affected.
2. It affects the electromotive force locally or generally.
3. It alters the skin resistance locally or generally, or
4. It affects insulation resistance locally.

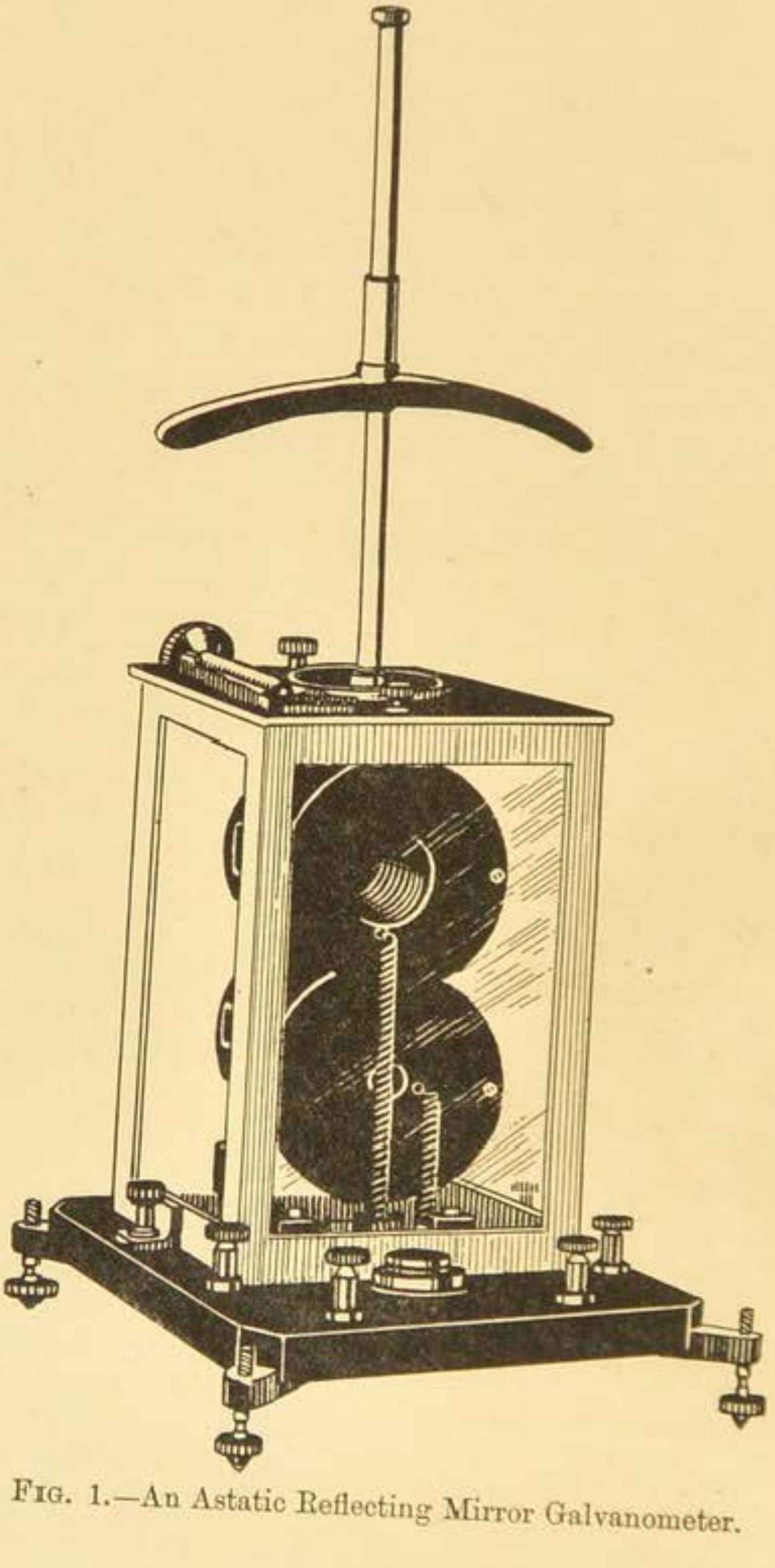


FIG. 1.—An Astatic Reflecting Mirror Galvanometer.

In each case there is a "fault," and before that fault can be dealt with its exact position and area must be defined and its character determined.

To do this it is only necessary to have two single contacts and a recording instrument sensitive enough to measure the natural human current flowing from any and every part of the human body.

But—unfortunately there is a "but"—there are many difficulties in the way of the general medical practitioner.

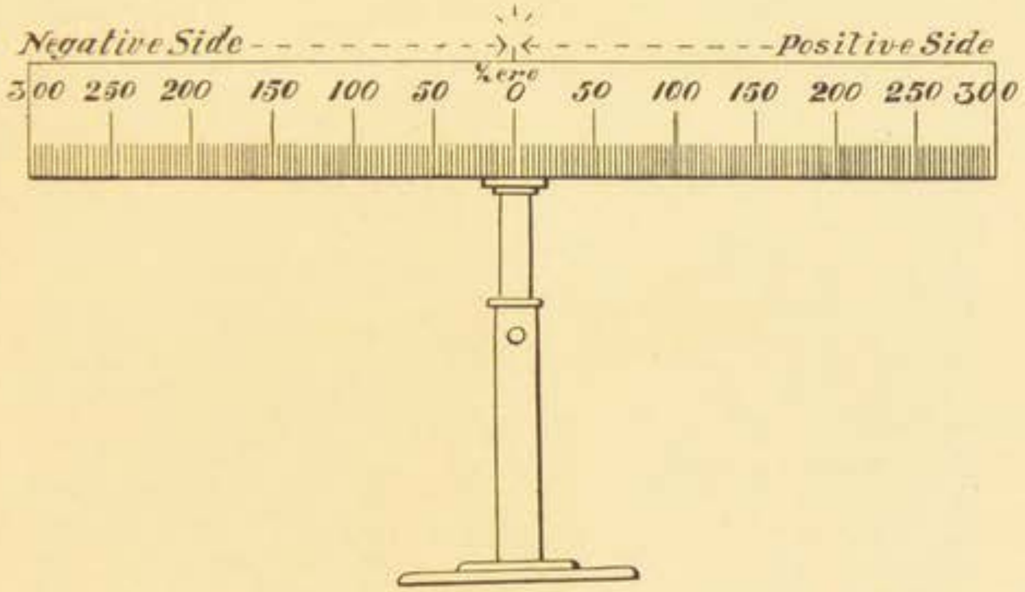


FIG. 2.—Scale upon which the deflections were recorded in millimetres.

The recording instrument is not portable in working condition, nor can it be installed within a mile of an electric railway or tube, by reason of induction, nor must it be subjected to any vibration whatever. On the other hand, it is only in the very early stages of disease, or when the medical man is confronted with an obscure disorder, that he is in doubt, and then he, as a rule, sends his patient to a specialist.

The apparatus required are a sensitive Astatic mirror galvanometer, suitably mounted; a short circuit key; a supply of flexible wire; and certain electrodes and contacts.

Preferably the galvanometer should be provided with a transparent scale, so that it can be read at a convenient distance from the instrument.

The electrodes used by me were of two kinds. To take the hand-to-hand deflection I found silver, as having a low coefficient in regard to increase of resistance with temperature, more reliable than copper, and, in order to avoid undue heating from the warmth of the hands, had the electrodes made solid. They were shaped as follows :—

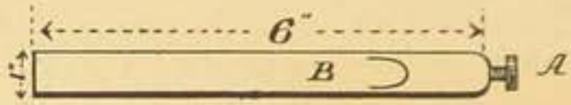


FIG. 3.—" A " is the terminal to which an insulated flexible wire is connected, and " B " a shaped piece for the thumb, of a section of ◡, so that contact with the sides as well as the under part of the thumb was assured.

When one of these was held in each hand by the patient and both electrodes were connected to the terminals of the galvanometer thus—

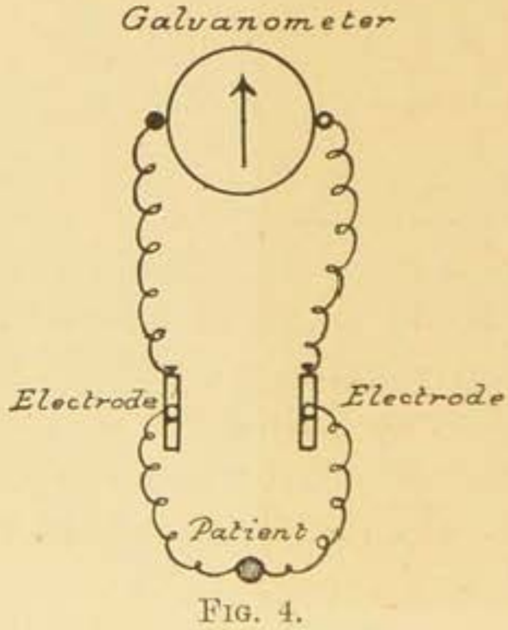


FIG. 4.

a deflection due to the patient's nerve current passing through the coils of the galvanometer was obtained, and

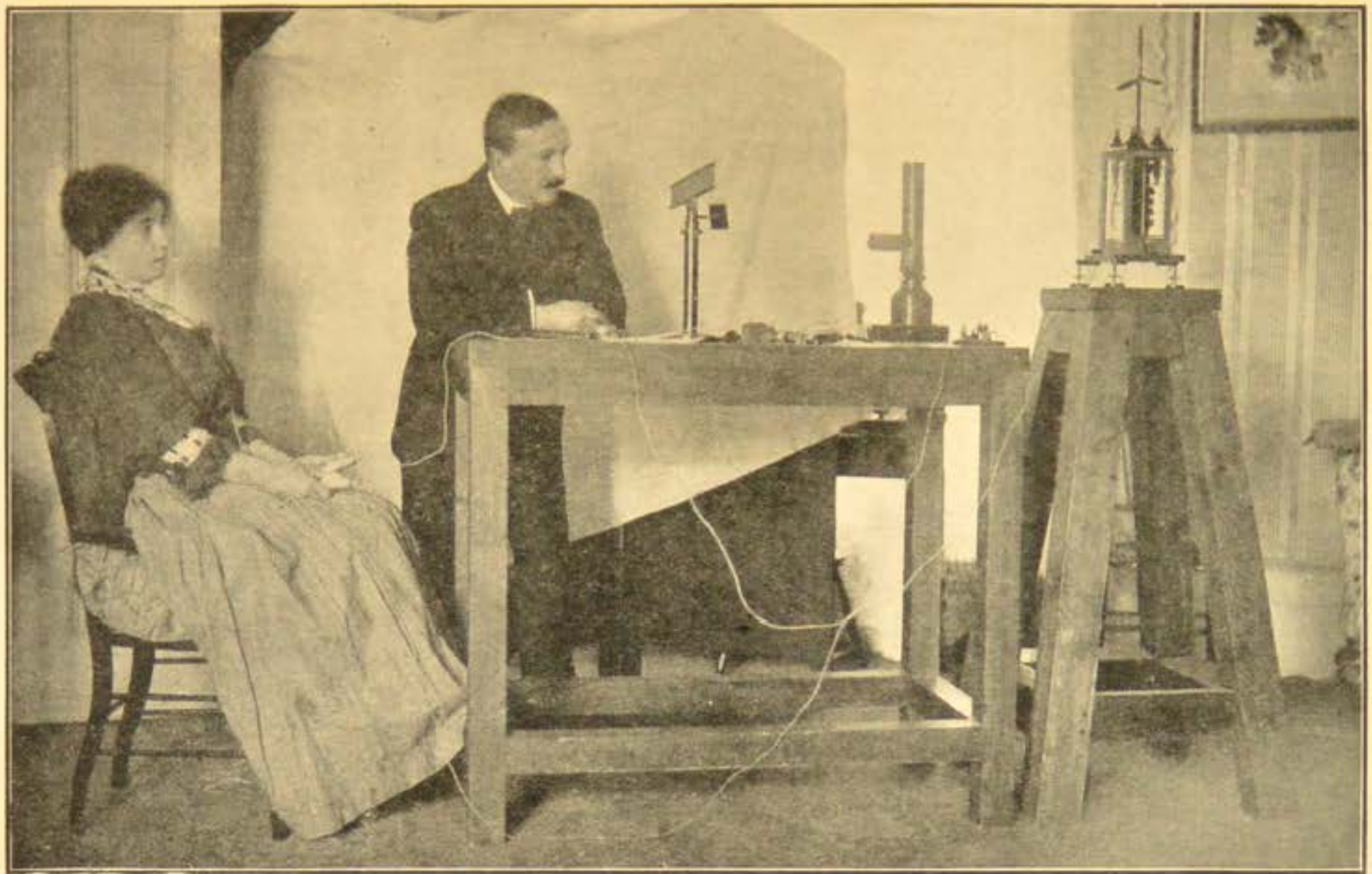


Photo by "Fotoco."

Fig. 5.—Showing the method of taking the hand-to-hand deflection, and the galvanometer, lamp, and scale as they were mounted.

this deflection, if carefully taken, gave an indication of the nerve energy of the patent. By "carefully taken" I mean that the patient must first be "put to earth" to remove any induced or other charge, the temperature of the electrodes must be watched and the test repeated several times to avoid error.

The other electrodes consisted of an elastic (rubber) band to encircle the head, provided with a circular plate (1 inch diameter) of pure silver carrying a silver terminal,

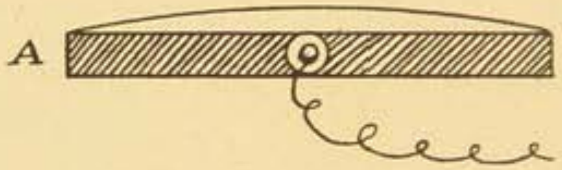


FIG. 6.

and a number of others "B"

FIG. 7.

which differed only in regard to the size of the silver boss *a* with which it was intended to make contact.

Both "A" and "B" are shown in use in Fig. 9, but further explanation is necessary.

The electrode "A" was designed for a central contact from which all measurements could be taken and the flat surface of the circular silver plate carried by it was so arranged as to be in close contact with the skin in the exact centre of the forehead of the patient. By means of its terminal it was then connected by a flexible wire to one terminal of the galvanometer coils, while the other terminal of the galvanometer was similarly attached to one of the electrodes "B" in the manner shown in Fig. 8, so that when any part of the skin of the person under examination was touched by the operator with the silver boss *a* of the electrode "B" the circuit would be completed and a deflection observed upon the galvanometer scale.

Now whether the silver plate forming the central contact shown upon the forehead in the above figure be our starting or finishing point does not in this instance matter very much, because the deflections are merely comparative. Given exactly the same skin resistance at each point of contact we know that the longer the distance, along the

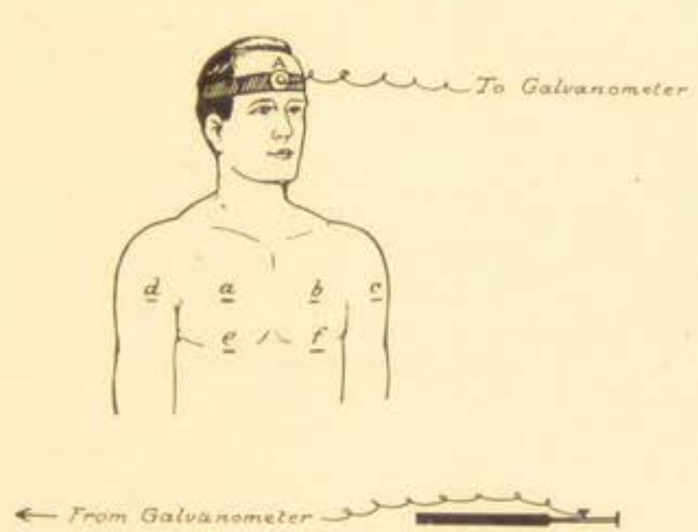


FIG. 8.—Method of Testing.

line of a given nerve, between the two contacts, the lower will be the deflection because $C = \frac{E}{R}$. Theoretically also we should get precisely the same reading from two precisely similar points—such as the spots I have marked *a* and *b*, *c* and *d*, and *e* and *f* in Fig. 8, but if we call the head plate "A" we should not get the same reading from "A" to *f*, as from "A" to *b*, or "A" to *c*; nor do we. I am, of course, speaking of normal conditions of health. But if "A" to $a = 100$ millimetres "A" to *b* should $= 100$ millimetres, and this rule should apply to any two similar parts of the body; to the tip of each little finger, to

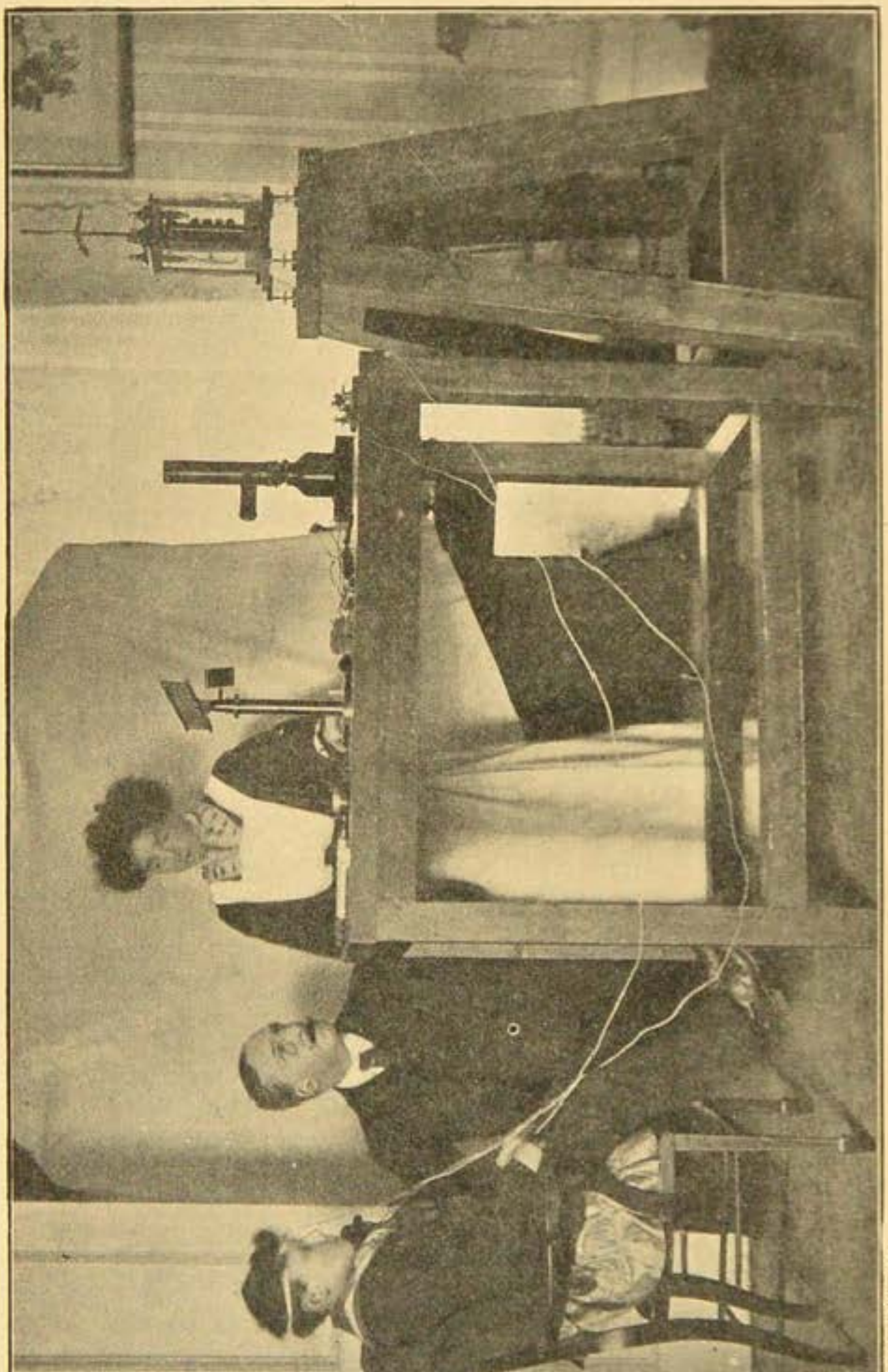


Photo by "Fotoca."

FIG. 9.—Showing the method of taking comparative deflections from a central (forehead) contact.

the end of each big toe, etc., but not to any intermediate part.

Change Produced by Disease.

But if either of the points, say *a*, happened to be affected by disease the deflections from "A" to *a*, "A" to *b*, would not correspond. That from "A" to *a* would be higher or lower than from "A" to *b*, which would remain at 100 millimetres. By touching the skin round *a* the *extent* of the area of the trouble could be accurately defined, while the rapidity of the deflection, or otherwise, would enable the observer to form an estimate of its gravity.

Nerve Cells and Nerve Fibres.

We may now consider nerve cells and nerve fibres in so far as they form part of the neuro-electrical system of man.

Nerve or ganglion cells occur in large numbers almost solely in the brain and spinal chord. From an electrical point of view they are condensers and storage cells, and each one connects with a number of delicate fibrous processes which either communicate with other nerve cells, or pass through the body to end in some organ. The brain is the seat of the intellectual life of man. Volition and imagination—to quote from a recent work—and the processes of thinking and perceiving originate in the nerve cells and are dependent upon them. If all the nerve cells of the human body suddenly ceased to act, all intellectual life would come to an end at the same moment, but if only some of them were destroyed, only that part of mental activity which resided in the destroyed cells would be lost. There are also nerve cells whose only duty it is to preside over the functions of speech and so on.

Nerve fibres are the continuations of the processes of the nerve cells. Their course is from brain and spinal cord, and they are really insulated wires carrying messages from the brain and spinal cord to the various organs of the human body. The brain may be regarded as the central station or departmental telegraph office, and the nerve fibres as the telegraph wires, which run from it to the smaller sub-stations—the organs of the body.

The nerves and nerve fibres are classified according to the organs in which they terminate, as: Motor nerves; secretory nerves; sensory nerves; and nerves of special sense.

Motor nerves terminate in muscle. Before a certain muscle contracts the impulse to do so originates in one or more cells in the motor area of the brain. In other words a message must be sent *from* the brain and *received by* the muscle before there can be any contraction or movement.

Secretory nerves are those ending in a gland, and like the motor nerves only convey messages *from the brain.*

Sensory nerves and the nerves of special sense serve as carriers of sensations from some point of the body *to the brain,* and the impulses therefore must travel in a direction opposite to that of the motor and secretory nerves. They may, in fact, be likened to signal stations, looking out for and transmitting intelligence to the central office for that office to act upon.

We are very far yet from comprehending even vaguely the ramifications of this wonderful telegraphic system, and I have only made a brief reference to the duties of nerve cells and nerve fibres with the object of suggesting an explanation of the negative and positive, or upward and downward currents, which are met with in different parts of the body.

EFFECT OF INFLAMMATION OR TEMPERATURE.

Before further illustrating my meaning by giving actual results I propose to call attention to the electro-pathology of inflammation.

From this point of view temperature acts upon the nerve sheaths and possibly upon the walls of the arteries and veins by breaking down the resistance of either or both so as to cause a leakage, or short-circuit, of neuro-electric current in the part affected, *i.e.*, the nerve current escapes

FIG. 10.—Showing how the Deflection is Altered by Local Pyrexia.

from the part or parts so affected into wet tissue instead of pursuing its proper path; one result being that when nerve sheaths are so affected certain blood vessels are deprived of part or all of their supply.

If then the part *a* (Fig. 8) was in an inflamed area the deflection from "A" to *a* would be higher than that from "A" to *b* and the rapidity of the deflection would be in proportion to the acuteness of the disorder.

Fig. 10 will sufficiently explain this, but experience alone can enable the observer to appreciate the speed with which the spot of light travels from zero to its ultimate position upon the scale.

I do not think it can be disputed that one effect of inflammation, no matter what its cause or where it may be, is, as I have said, to break down insulation resistance. Dr. Stone and I both arrived at this conclusion—though by different methods—in 1885, but though we have been told much of electrical, I have yet to hear of dielectrical treatment. If we compare a nerve in its sheath with a guttapercha-insulated copper wire we know that the effect of temperature is to increase the resistance of the copper and decrease the resistance of the guttapercha. As to whether in the case of the nerve the analogy altogether holds good I am unable to say positively. It would be both interesting and valuable to test the conducting nerve for resistance with ascertained temperatures, and determine a coefficient; but the difficulties in the way appear to be insuperable. One fact, however, is known. Temperature decreases the resistance of the nerve sheaths and may temporarily destroy it, and as the nerves are surrounded by wet tissue an inevitable result is a leakage of nerve energy, in the part, or parts, inflamed, with the result, as I have remarked, that certain blood vessels are deprived of part or all of their supply of current. Now if we connect a wire with a known source of electrical supply we expect to get from the other end of the wire an amount of current in accordance with Ohm's law, $C = \frac{E}{R}$, or in other words a current equivalent to the electromotive force divided by the resistance of the wire. If we do not obtain that quantity of current the existence of a "fault" is established and we must test for and find it in order that it may be repaired. In electrical practice this is very simply done because the wire has a known resistance of so many ohms or units of resistance per mile, and we have only to measure the resistance to the fault to ascertain its exact distance from the testing station. Now the human body does not offer anything like the same difficulty. A test as in Fig. 11 will at once reveal the presence, locality and gravity, of the disorder by the extent and rapidity of the deflection as compared with the extent and rapidity of a deflection from a corresponding *unaffected* part of the body. Suppose for instance only the right lung was inflamed. The deflections would be, roughly, as follows:—

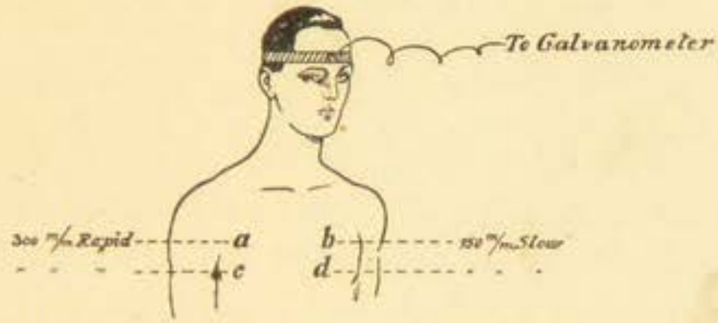


FIG. 11.—Illustrating the Deflections due to Extensive Inflammation of the Right Lung.

In this case it is quite clear that electrical treatment cannot be other than harmful. We cannot remedy a partial fault in a wire by putting current through it, but we may by so doing increase its extent. Nor, reverting to the human body, do I see what curative value there is in a warm poultice, except as giving relief by decreasing the resistance of the skin and underlying tissues, and so affording a larger area of decreased resistance to the passage of the leaking nerve current to the air. To my mind the treatment indicated by this electro-pathological condition of inflammation is dielectric treatment. We should effect a repair of our wire by putting some more guttapercha over it at the fault, and we should, I venture to think, adopt as a curative measure of the first importance the restoration of the insulation of the nerve sheath, or wall of the artery or vein affected.

It may be urged that this cannot be done. It can be very easily and effectively done. It has been done very many times, and in every case the treatment was successful.

What is wanted is a harmless *insoluble* and undecomposable fluid of very great penetrative power and *high resistance*, a fluid which when applied outwardly by means of a pad of cotton wool can be relied upon to reach the seat of inflammation in an hour or so and to *stop the leak;* a fluid which, moreover, can also be taken internally: as internally such a dielectric cannot fail to be of value in cases of appendicitis, gastritis, and other and similar disorders. My suggestion therefore is to supplement the ordinary treatment of inflammation by making full use of the endosmose and exosmose action of such a fluid—a liquid indiarubber, in fact, without its disadvantages and with the additional property of great penetrative power. Any member of the medical profession can have its formula upon application.

In pneumonia there is the additional difficulty of the bacilli, but they can be rendered inert and and deprived of sustenance by the process of staying and curing the inflammation, and they have not been found in practice to present any element of danger to life when the dielectric was promptly applied.

I could quote many cases of double pneumonia where the temperature has been 105·5° and 106° F., and show that in every such case the temperature fell to 101° within an hour of the dielectric being applied and that rapid recovery followed. The following case of acute appendicitis is, however, typical and is particularly interesting because the temperature, pulse and respiration were taken almost hour by hour by a trained nurse appointed by the physician in attendance.

The patient was a girl of 12 years of age, and it was said by the medical specialist that if she was not operated upon within twelve hours her life could not be saved. In less than one hour after dielectric treatment she was practically out of danger.

The following are the figures :—

Time.	Temperature.	Pulse.	Note.
9.30 p.m.	103·3	127	Dielectric applied 9.30 p.m.
10.20 „	101·2	120	
11.0 „	101·4	116	
11.30 „	101·2	112	
3.0 a.m.	100·8	108	Second day.
7.0 „	100·2	108	
9·30 „	100·4	104	
11.0 „	100·2	102	
Noon	100·2	98	
1·0 p.m.	99·3	84	
3·0 „	99·3	84	
6·0 „	99·3	80	
9·0 „	99	80	
Patient slept all night.			
7·0 a.m.	99·2	88	Third day.
6·0 p.m.	98·4	75	
Patient slept all night.			
7·30 a.m.	98·6	80	Fourth day.
4·30 p.m.	98·4	70	

And after that time the patient retained a normal temperature, regained strength and shortly afterwards went to the seaside.

It is worthy of note that fifty minutes after a pad soaked in the dielectric was placed over the appendix and two ounces administered by the mouth, the temperature had fallen from 103·3° to 101·2°.

The Treatment of Local Pyrexia considered in relation to the Cure of Tuberculosis.

Commenting upon Professor Ehrlich's address in Pathology on Chemotherapeutics, delivered in general session of the last Medical Congress, *The Lancet* observes: "Is it too much to hope that in their turn tuberculosis and cancer will become controllable?"

This is nothing if not an admission that in regard to the treatment of both diseases we are still in the experimental stage and that apart from the improvement in public health due to better sanitation, to precautionary legislation and the establishment of sanatoria, no advance has been made in the direction of discovering a cure for consumption. Specific remedies innumerable have been tried, but of these "Tuberculin" alone retains some semblance of vitality.

In regard to it we have only to read the opinion expressed by Sir James K. Fowler, M.D., F.R.C.P. Lond., to come to the conclusion that not only is it not a remedy for tuberculosis, but that it not infrequently tends to increase the gravity of the disorder. Sir James says: "Its use is absolutely inadmissible in any case in which there is fever" (*i.e., temperature*). And further: "Fever is, as I have always taught, the guide to the activity of the disease: and therefore the *rôle* of any remedial agent which can only be employed in afebrile cases is necessarily very limited." This statement was published in *The Lancet* of August 9th, 1913, and being from so eminent an authority as Sir James Fowler may be accepted as the last word so far said upon the subject of a remedy for the disease. The strongest argument against the use of tuberculin from my point of view is that it, when hypodermically injected, sets up local pyrexia, and by so doing facilitates the continued propagation and active existence of the bacilli.

I am aware that the medical profession is divided into two camps of opinion of tuberculin, but those who believe have little more to urge in its favour than that in incipient cases it is harmless. They admit, however (Professor Dr. Sahli), that "as a rule acute cases cannot be treated by tuberculin."

If these facts are examined in the light thrown upon them by Dr. Bowman and myself it becomes, I think, quite clear that one thing imperatively called for is a rapid and certain remedy for local pyrexia, and that if our explanation of the electro-physiology and pathology of pyrexia is not accepted such remedy is not at present known to science.

I revert to Sir James Fowler's statement that "the *role* of any remedial agent which can only be employed in afebrile cases is necessarily very limited." *There is no remedy,* qua *remedy, for pyrexia in the pharmacopœia of the world.* There are, it is true, *subsidiary remedial agents* of which intelligent use may be made, but not *a* remedy.

Now if I may go back to, and to the extent of one synonymous word paraphrase Sir James Fowler's statement in regard to tuberculin, *i.e.*, "Its use is absolutely inadmissible in any case in which there is temperature," the issue becomes clearer.

I repeat that temperature, from the standpoint of the electrician, breaks down local insulation resistance.

From this point of view local pyrexia must mean, in technical language, a shunt of varying resistance.

The treatment I have suggested is to stop the leak by means of the endosmose, and at times the exosmose, action of a suitable dielectric.

The immediate relief and arrest of the inflammation, whether internal or external, are effected, as I have said before, by the application of a non-irritating and undecomposable solution, easily absorbed and far-reaching in its effect upon the disturbed blood vessels of the inflamed parts, even if deep seated. This effect is due to the toning up of the vasomotor nerves and constriction of the dilated blood vessels of the inflamed area immediately the dielectric is applied, with the result that heat, redness, pain, swelling, and temperature disappear *within a few hours.*

Theory teaches and experience has shown that not only must and does this occur, but that the bacilli are almost at once rendered inert, and—I cannot too strongly emphasise it—thereafter give no trouble which is not in the power of the ordinary medical practitioner to deal with.

And now allow me to digress for a moment.

Hitherto all attempts to deal with what is known as the "white scourge" have been in the direction of introducing sera or drugs into the blood with the object of killing the bacilli. They have all failed. Partial success has been achieved by carefully regulated diet, by fatty foods and dry cold air. Now fatty foods tend to conserve insulation, and so does cold *dry* air. In other words, they are, in a sense, remedies for pyrexia, as moist air and abnormal acid or alkaline conditions of the blood favour its continuance. In the first case we have dielectrics, of a sort, and in the second, conductives favouring the progress of inflammation.

And now let me give a few approximate figures descriptive of the usual neuro-electrical conditions which obtain; figures which I have not considered before because as the deflections are always comparative, it appeared, and still appears, to me to be unnecessary to express them in units or fractions of a unit.

For purposes of comparison it may be taken that a deflection of 250 millimetres rising steadily upon the scale of my galvanometer would be due to about ·004 volt and ·01 milliampère, while the resistance of the path to air, including the resistance of the skin, would be about 43,000 ohms.

Now, in local pyrexia, say in the lung, it does not follow that the skin resistance is sensibly decreased, while that of one or more nerve sheaths may be reduced to almost nothing. The result is a much higher deflection, say 1,000 millimetres in an acute case, through the affected area, and as the potential of the nerve-energy has not increased it follows that the natural insulation resistance in the affected part has been decreased.

Taking the above figures as a basis, it would appear that a deflection of 1,000 millimetres would be due to ·004 volt through 11,000 ohms, and as we may safely estimate the average skin resistance at about 10,000 ohms, such a deflection would indicate that the pyrexia giving rise to it had lowered the interior insulation resistance by 32,000 ohms, or in other words had reduced it from 33,000 to 1,000 ohms.

The resistance of the liquid dielectric I employ is *infinity* at a temperature of 60° F., but as in the case of all dielectrics with which I am acquainted, its resistance decreases rapidly with temperature, and it must therefore be artificially cooled, preferably by standing the bottle in crushed ice.

Another point of importance is its specific gravity, not only in regard to its absorption of oxygen both by selection and as a vehicle, but also to the influence specific gravity has upon endosmosity. Furthermore, the least trace of acid or oxide of iron or other and similar conductive impurities may not only impair, but utterly destroy its usefulness.

There were many statements made at the last Medical Congress which afford some measure of corroboration of what I have said. Dr. C. Bolton (London) showed that gastric ulcer spread much more rapidly and healed much more slowly on a meat diet than on a milk diet. In meat there are the conductive potassium salts: in pure milk we have a semi-dielectric.

Dr. M. Price (Niagara Falls, U.S.A.) said that he had had the opportunity of examining workers in graphite, calcium carbide, and carborundum, who worked in clouds of dust, and stated that the mortality in Niagara Falls stood at a higher rate than that in any other part of the State.

Admitting the presence of the bacillus of tuberculosis in the blood, the constant breathing of moist air would sufficiently account for a high mortality, as a common cold would be enough to set up a condition dangerous, in such circumstances, to life.

It is not difficult to accumulate evidence that the action of a dielectric—almost any dielectric—is to, in a greater or lesser degree, check inflammation; but in the absence of knowledge of the electro-pathological features of local pyrexia, we have merely a number of seemingly unconnected facts instead of a sequence of proofs.

Pleuro-Pneumonia and Scalds.

In the case of pneumonia the outward application and internal administration of a suitable dielectric are sufficient to remove danger to life, while burns, no matter how severe, are rendered painless in a few seconds after a pad soaked in the dielectric is placed upon them; blisters having first been dispersed.

But in pleuro-pneumonia and scalds we have a different condition to deal with because of the presence of water in the tissues, and it becomes evident that the dielectric employed in such cases must have a specific gravity greater than that of water; otherwise it cannot be relied upon to reach the seat of pain and immerse the leak or leaks in a bath of non-conducting fluid. I would give the formula of such a dielectric here, but the average layman is liable to err in the matter of diagnosis, and in certain forms of disease the application of the dielectric I have in mind might be dangerous. It is, however, as I have said before, at the service of any medical man.

Experimental Treatment.

Much of the treatment of disease has been and is, of necessity, experimental, and it is only after more or less prolonged periods of time that any conclusion as to its merits or demerits can be arrived at. In diseases of the heart and circulation opinions are divided in regard to the administration of digitalis, strophanthus, caffeine, convallaria, coronilla, belladonna, atropine, and a host of other things; in asthma and bronchitis pyridine, nitro-glycerine and creosote inhalations have been tried with uncertain results; in pneumonia the serum of immunised rabbits, serum from convalescents, digitalis, and strychnine, have yielded nothing of value; in tuberculosis, cancer, and many other diseases we have not even an apology for a remedy.

Nor have we any conclusive data as to the therapeutic value of X-rays and radium from the thousands of experiments carried out by competent men, and one cannot help feeling that something must be radically wrong with a method which calls for the exercise of so much ingenuity and gives so little in return.

Since the above was written Sir Frederick Treves has made a statement of the utmost importance in regard to the treatment of cancer by radium emanations. I sincerely hope it is true, but history is given to repeating itself, and we were assured not many years ago that Koch's discovery had brought tuberculosis within the range of curable diseases. Even if it is true, my argument is not affected. A blind man shooting at the sky might bring down an occasional bird, but the hungry would find little consolation in the prospect.

If it is a fact, as I assert, that any physical change in the body must be attended by a neuro-electrical change, and that the process of restoring one to normality tends automatically in the great majority of disorders to restore the other to normality, we have in the Astatic galvanometer a means of determining, from hour to hour if necessary, exactly what, if anything, is being accomplished.

Disease is a deviation from the state of health, implying some alteration in the functions, properties, or structure of some organ or tissue, and may be generally described as an abnormal performance of the processes constituting life. That being so, it would be illogical to imagine that one of the most delicate of those processes, *i.e.*, the maintenance and regulation of the neuro-electrical ions could proceed without deviation in any diseased area.

Suppose, for instance, that increased resistance of the tissues is one of the principal electro-pathological features of cancer and that we obtain the measure of that resistance by taking a deflection due to the passage of nerve energy through the affected part to air and comparing it with the deflection obtained from a corresponding (unaffected) part of the body. We should then have two figures, say 25 millimetres from the cancerous, and 250 millimetres from the normal area.

Let us also assume that the cancer is being treated with radium and that the first application has been made. To be beneficial the deflection from the cancerous area should be higher, showing decreased resistance of the tissues. If it is not higher, then it is fairly certain that no good has been done, while if it is lower the action of the radium would appear to have been harmful.

Similarly in tuberculosis the slightest increase or decrease in the area of the tubercle could be detected as well as any variation, no matter how small, of local pyrexia long before either made itself determinable by other means; while the efficacy or othewise of any drug could be definitely ascertained in the same way without loss of time.

Due regard must, however, be had in every case of improvement, as indicated by the galvanometer, to its duration. For instance, a stimulant of any kind may, and indeed will, increase the potential of nerve energy, but if the increase is merely temporary it may be purchased at too great a cost.

Induction and Research.

It may, possibly, be thought that I am not acquainted with the fact that many, if not all, of our large hospitals are equipped with the instruments required for research work upon the lines I have indicated. I am, however, not only aware of it but have endeavoured to explain why the results obtained by medical electricians have failed to agree. Years ago it would have been possible to obtain accurate data, but since the advent of the electric railway, induction has, generally speaking, interposed an insuperable obstacle. There are very few hospitals in London, or, indeed, in any of our large towns situated more than three quarters of a mile from an electric railway or tube, or from mains carrying current of high potential, and whenever the laboratory is situated within that area the inductive influence of the high potential current upon the body of the patient is such as to negative the possibility of testing. In my early days of submarine cable testing we were not allowed to use more than 20 volts, and I have found the earth currents in Eastern Africa to exceed 40 volts for weeks on end, rendering all my efforts abortive. Not long ago I, in order to demonstrate the difficulty of overcoming induction, installed an Astatic galvanometer at Holbein House, near Sloane Square District Railway Station, and tested several persons whose hand-to-hand deflections had previously been determined in my laboratory outside the radius.

Now, there is a current traversing the "up" line, of a certain potential, and another current of equal potential, but opposite sign, traversing the "down" line, and the body of the patient possesses high inductive capacity.

While both trains are three-quarters of a mile or more away there may be a compensating inductive influence upon the patient's body, but the moment *one* train passes the border line an *alteration* in potential is brought about and the equilibrium disturbed.

What actually happened was that a subject whose predetermined hand-to-hand deflection equalled 200 millimetres positive in my laboratory gave a deflection of off-scale positive when an up train came in, a deflection of off-scale negative when a "down" train came in, and zero when both trains arrived simultaneously. Moreover, the inductive influence varied almost from second to second.

Functional and Central Paralysis.

Our knowledge of the electro-pathology of cranial disorders may be summed up in the words of Drs. Beard and Rockwell ("A Practical Treatise on the Medical and Surgical uses of Electricity"). They say (p. 460): "It must be confessed, however, that the exclusive use of central galvanisation is far from being satisfactory, and for these four reasons:

"First. With all our improved methods of diagnosis it is impossible to fix with anything *more than approximate certainty* the seat or even the nature of the morbid process in diseases of the brain; hence, all localisation of the galvanic current in this or that part of the head must at best be empirical and tentative.

"Secondly. *It is impossible to localise the galvanic current entirely in any small portion of the brain.*

"Thirdly. Diseases of the brain are usually accompanied and followed by general feebleness that demands constitutional treatment, and

"Fourthly. The paralysis will not yield to merely central treatment directed to the seat of the disease, but must be treated itself." The italics are mine.

I must confess to some astonishment at the statement that "it is impossible to fix with anything more than approximate certainty the seat . . . of the morbid process in diseases of the brain"; more especially when the fault is, as it generally is, in the motor area. Difficulties there are, undoubtedly, but it is not impossible. Every motor nerve is a line wire "earthed" through the skin, and having its source of power and the intelligence directing it in the motor area of the brain. Surely the line wire can be tested, and the nature, position, and extent of the fault localised by the method I have described. The chief obstacle in the way is the hair, and in order to obtain reliable results it is really necessary either to shave the head or to at least remove the hair in the suspected area and to thoroughly cleanse and dry the scalp. When that has been done I have invariably been able to locate and determine the nature and area of the fault in all the cases (some forty in number) submitted to me even when the pathological condition was fibrosis at the place of lesion. The latter was a solitary case and I failed, and still fail to see what possible good could be hoped for from electrical treatment of any description.

Of paralysis in the young many cases have come under my notice, and in very many of them it is quite unnecessary to test. The finger or hand can be at once placed upon the affected part and the trouble found to proceed from the use of instruments at birth (a very common cause), to a fall or a blow, unnoticed at the time and long forgotten until recalled to memory. A distinct depression or depressions can generally be felt, and from these depressions no nerve current or a subnormal current issues. If, moreover, the motor nerve at its terminal is tested in conjunction with the nerve cell, or cells, serving it, no deflection or a sub-normal deflection—in accordance with the gravity of the disorder—will result.

Paralysis: *Agitans.* — This was a typical case of Parkinson's disease in a man aged 72; acute for four years. While the palsy might be said to be general, it appeared to be more pronounced in the left arm and right leg. His temperature was subnormal. There was great loss of vitality. All the muscles were more or less impaired. Excessive nervousness and depression were prominent. The complexion, however, was good and the eyes clear. Also there was no suspicion of the trouble being of syphilitic origin.

In this instance the patient was quite bald, and we fixed the central contact plate just above the occipital protuberance instead of upon the forehead, and took the following deflections from it to the localities below mentioned. His temperature was 97·4° F., and the hand-to-hand deflection 235 millimetres positive; a deflection which would compare favourably with that of a man in good health.

From the central contact plate to :—

1. The left lobe of the brain gave 220 millimetres positive.

2. Centre of the cranium, 110 millimetres positive.

3. Right lobe of brain, 240 millimetres positive.

4. Left lobe of brain, slightly nearer forehead, 20 millimetres positive.

5. Central line, slightly nearer forehead, 35 millimetres positive.

6. Right lobe, slightly nearer forehead, 105 millimetre positive.

7. Left shoulder, 230 millimetres positive.

8. Left wrist, 15 millimetres positive.

9. Left mid-arm (inside), 3 millimetres positive.

10. Left mid-arm (outside, above elbow), 60 millimetres positive.

11. Left mid-arm (outside, below elbow), 120 millimetres positive.

12. Just above navel, 2 millimetres positive.

Those figures are very perplexing; more especially when the hand-to-hand deflection is compared with that from just above the navel and the subnormal temperature is taken into account, the latter being indicative of a subnormal deflection. It is, however, clear that as regards the brain itself Nos. 4 and 5 point to a fault at each of those points, while between the left shoulder and the left wrist (itself faulty) Nos. 9 and 10 are suggestive of increased local resistance in or local atrophy of a conductor or conductors, or a local morbid condition of the muscular tissues. The legs were not tested.

With the atrophied (if it was an atrophied) condition, we did not attempt to deal beyond recommending brine baths with a view to increasing conductivity, but proceeded to affix a small and very thin silver plate to each of the points indicated by tests Nos. 4 and 5 (20 millimetres and 35 millimetres respectively), connecting them together, and an elastic belt, carrying a circular silver plate provided with a terminal round the waist in such a manner that the circular plate was in contact with the skin about an inch above the navel. To these we connected, by means of fine flexible wires, a small dry cell of an electromotive force of slightly over one volt, with its positive terminal to the head plates, and its negative terminal to the body plate, the object, of course, being to, if possible, supply a continuous current of low potential and quantity where it appeared to be wanted.

This treatment no doubt left much undone, but it reduced the palsy to a slight and only occasional trembling. It enabled the patient to sit down and arise without assistance, to open and close his hands, to cut up his food, and dress and undress himself, and it, moreover, removed the depression and brought about a normal temperature. These effects were, so far as I know, lasting. I say, so far as I know, because the patient left a few days afterwards for abroad, and beyond hearing some weeks later that the improvement was maintained, I know nothing further.

Paralysis of the Left Leg and Foot.

This was a girl aged 16, and her left leg and foot had been paralysed for thirteen years. During that time she had been under medical treatment at home, at the Orthopædic and Westminster Hospitals, she had had a long course of massage and magnetic treatment, and finally given up as incurable. Her head was never examined.

The earliest symptoms were pronounced vomiting, followed by paralysis. When I saw her the left leg was emaciated and in a condition of arrested development. The patella was very small and shifted under the finger, the Achilles tendon was not defined and the foot appeared to be a shapeless mass of white flesh below a swollen and misshapen ankle. She had not been able to move her toes for thirteen years.

Slightly to the right and rear of the centre of the cranium I found a distinct depression, and from this depression we got no deflection. Her general health was not satisfactory, her hand-to-hand deflection being 70 millimetres positive to 70 millimetres negative (neurasthenic), and a reading from the centre of forehead to middle of foot not exceeding 10 millimetres. From the centre of forehead to the centre of the right foot gave 70 millimetres positive. Her temperature was 97° F.

We then carefully shaved the hair from the locality of the depression and, as in the previous case, fixed a thin silver plate to the supposedly affected spot, and round her waist placed an elastic belt carrying a circular silver plate provided with a terminal, in such manner that the circular plate made contact with the skin on the left side of the body just above the hip. These were connected as before, with a small dry cell (which the patient carried about) of an electromotive force of 1 volt + to head and — to left side.

Fifteen minutes later the hand-to-hand deflection was 300 millimetres positive; from the centre of forehead to the centre of left foot and right foot it was 300 millimetres positive. She was then able to move her toes *slightly*, the swelling went down, the toes became pink and healthy, and her temperature went to normal.

Four days later her hand-to-hand deflection was still 300 millimetres positive, but the centre of forehead to left foot deflections varied considerably.

Fig. 12.
Diagram of Foot, with Paralysis.

The part shown in black exhibited low vitality, and we increased the current to 2 volts with excellent results, for a week later the foot was perfectly pink and healthy, there was increased animation in the toes, and the leg, from being flabby, was beginning to be firm. A month afterwards the deflections were 300 millimetres everywhere, the leg was filling out, the ankle becoming firmer, the Achilles tendon perceptible, and the patella *growing*. In six months only a slight lameness characterised her gait and I considered her cured. The original cause of the trouble was a blow with the corner of a slate.

I could give many other cases, but it would not serve any useful purpose, as whether the affected area was large or small, the condition curable or hopeless, the features of damaged nerve cells or atrophied conductors giving little or no deflection were always present. One other case, however, may prove of interest as it goes to show that the methods I advocate are not always by themselves sufficient to effect a cure. It was variously diagnosed by four specialists as "petit mal," paraplegia spasmodica, paraplegia hysterica, and hysteria, and the patient was a woman aged 26 years. The symptoms were loss of control over limbs, movements uncertain, jerky, and exaggerated. The left side was first affected, the right side apparently only sympathetically so.

I found a slight depression slightly to the right and towards the rear from the centre of the cranium, from which we got no deflection. She was certainly paralysed to a certain extent, and under treatment she improved considerably, but hysteria was responsible for part of the condition. On the first occasion she was brought to me in a cab and supported by two nurses. On the second occasion she came by train and was accompanied by one nurse only. Also she was able to walk fairly steadily without assistance and without holding on to such objects as she passed. But that was as far as we could get. She became violent at the mere suggestion of hot salt baths, objected to the head plate and offered a passive resistance to curative measures generally.

Now had it been a case of paralysis only, with the fault in the motor area of the brain, it would either have shown distinct signs of yielding to the treatment I have described practically at once, or it would not have yielded at all. If there was a lesion, for instance, it would not respond at all. I therefore came to the conclusion that while the first specialist was undoubtedly wrong, two of the others were not far from the truth.

The following case was not one of paralysis, though the medical diagnosis was paralysis of both wrists. The patient was a woman of sixty years of age, and she was quite unable to use her hands. I could not find anything wrong with the brain. Her hand-to-hand deflection was 100 millimetres *negative* unsteady, and the cranial readings were in accordance with it. But 100 millimetres *negative* shows a condition not far removed from anæmia, or, as I term it, "devitalisation," and assuming it to be such we applied a continuous current of 1 volt. She was able to shake hands before leaving and to cut up her food the same night. She had, of course, to wear the appliance during the daytime, but was eventually able to dispense with this.

Neurasthenia.

To my mind this disorder is one not only of vital importance, but one of which the pathology remains more or less obscure and also one which in its various forms is not always recognised and therefore effectively dealt with. It is generally known as nervous debility, but viewed from an electro-pathological standpoint it has a characteristic which differentiates it from any other irregularity of the nervous system with which I am acquainted and which I believe to be peculiar to neurasthenia alone. It certainly has one feature in common with anæmia, and that is a low deflection, but in all other respects it differs materially from anæmia, and has more association with hysteria and dementia than with nervous debility, or, in other words, with partial devitalisation. If I were asked to describe it I should make use of the term "nervous instability."

If we take the hand-to-hand deflection as the measure of neuro-electricity present in the body as a whole—in the same way that we should take the reading of a weighing machine of the total weight of a person—and we find that deflection to be subnormal it is in all probability due to deficient generation. An unusually thick and dry skin would interpose high resistance to the passage of current to air and so decrease the quantity of the current causing the deflection; but this would give rise to symptoms which could not be overlooked, while want of nerve conductivity would generally be attended by pain. Moreover, both could be detected by simple tests. The probable explanation, therefore, is, as I have said, defective and irregular generation of nerve force.

Now we have assumed our galvanometer scale to be divided into 300 millimetres on each side of zero, as in the

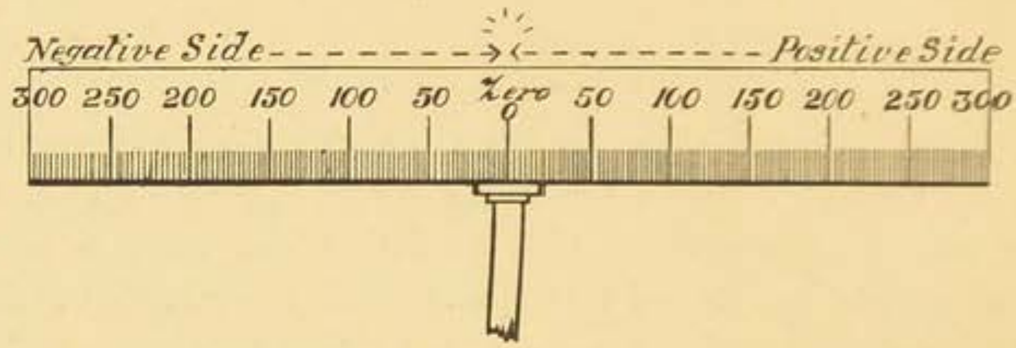


FIG. 13.—Scale of Galvanometer.

above illustration, and that the deflections are comparative. In practice the hand-to-hand deflection from a healthy person should be 250 to 300 millimetres, rising steadily and becoming constant at whatever point it halted. In anæmia the readings may vary from 15 millimetres positive or negative to 60 or 70 millimetres positive or negative, and the degree of weakness is shown by the smaller number of millimetres and the *sluggishness* of the movement of the spot of light upon the scale. But these deflections do not vary in true anæmia. There is a certain quantity of neuro-electricity present in the body, and we obtain the measure of it, and whether it be 5 millimetres or 50 millimetres, the light will go to one of these points and to no other point if the nature of the contact and pressure is unaltered. But in neurasthenia a very different phenomenon is observed. *The light is never at rest.* The deflection may be anything from 5 millimetres to 90 millimetres or so, but it will be both positive and negative, moving slowly and erratically backwards and forwards, sometimes pausing for a few seconds but never becoming constant, or giving any certain indication of the natural neuro-electrical sign of the patient. This irregularity, this fluctuation, combined with an insufficiency of nerve energy, is a peculiarity of neurasthenia, distinguishing it from other nervous affections and pointing, in my humble opinion, to some cerebral disturbance.

Curiously enough, the behaviour of the sufferer from neurasthenia is, as a rule, consistent with the peculiarity to which I have alluded. I have tested and observed some forty or fifty patients, and have found in every case not only the same neuro-electrical phenomena, but a corresponding fluctuation of will. Neurasthenic patients are slow to admit to others that there is anything wrong with them, and if treated will not long submit to the same treatment, but go from doctor to doctor or try a few doses of every quack medicine they see. They never seem to know their own minds, and in this respect at least their mental and neuro-electrical conditions appear to be in accord.

I will now give a few cases in detail :—

Mr. A. Aged 59 years. Complexion pale, temperature subnormal. Hand-to-hand deflection 70 millimetres positive to 65 millimetres negative; later 5 millimetres positive, unsteady. Very low electro-vitality as shown by all the deflections. This man had had many financial worries, was rather litigious and appeared to take his monetary losses to heart. It was difficult to persuade him to undergo treatment.

To try the effect of a mild continuous current of electricity we made him a belt carrying two circular silver plates, one making contact with the spine, and one with the abdomen just above the navel. To these we connected a dry cell of an electromotive force of 1 volt—negative terminal to back, and positive to front plate—and after ten minutes his hand-to-hand deflection=198 millimetres negative (falling). This was not satisfactory, and we therefore reversed the connections, when the deflection became 260 millimetres positive, and when taken ten minutes later steadied to 140 millimetres positive. The patient then reported that he felt better, and more cheerful. We tested him a fortnight later, when the appliance had been disconnected for four days, an found his deflection to be 180 millimetres positive. Upon restoring the connections it went to 292 millimetres positive, and the patient was in every way greatly improved by the treatment he had undergone. We, however, warned him that he was in danger of mental breakdown, that he must endeavour to forget his troubles, and continue to wear the appliance. That he did not do the latter is certain, because the dry cell had a life of one month only, and until he was certified insane some months afterwards we heard no more of him. He was, I was told, placed under restraint, and after being discharged as cured, committed suicide.

What follows is pure theory upon my part, but I cannot help thinking that the manner of his death was consistent with what I may call the neurasthenic fluctuation. He had shaved one side of his face, and after commencing to shave the other, cut his throat. Weak negative deflections, so my experience goes to show, coincide with mental depression, and I feel sure the fatal act was committed when the nerve energy had ceased to flow positively and a weak negative deflection would have been observable.

Now I do not mean to assert that the administration of a continuous current of electricity of small quantity and low electromotive force has a curative value in every case of this kind, but it seemed a sensible thing to do to restore the deflection to normal, and it cannot be disputed that during the duration of the treatment the man was distinctly better.

Miss B. Aged 40 years. She claimed to have been suffering from "neuritis" for 7 years, but as she had been under the Weir-Mitchell treatment at a hospital (without deriving any benefit) she was probably mistaken. Her hand-to-hand deflection was very unstable, and varied between 240 millimetres positive and 90 millimetres negative, halting several times at 15 millimetres positive. We then fitted an appliance similar to that in the last case and, after joining up, the deflection went to 250 millimetres positive, steady. After ten minutes it continued constant at 255 millimetres positive, and after thirty minutes was quite steady at the latter figure. The patient reported herself much better, and continued to be so.

Mr. C. Aged 28 years. Suffering from nervousness and depression; easily excited and especially sensitive to noise. More acute during last five years. Hand-to-hand deflection 170 millimetres positive, falling rapidly to 30 millimetres negative, after which it rose slowly to 115 millimetres negative. Temperature 97·8° F., not treated.

Mr. D. Aged 50 years. General health very unsatisfactory. Partially deaf. Hand-to-hand deflection 90 millimetres negative to 90 millimetres positive; sluggish. Made several appointments before coming and did not return.

Mr. E. Aged 81 years. Temperature subnormal. Hand-to-hand deflection 90 millimetres negative to 90 millimetres positive. Complained had had rheumatic pains in both hips for eighteen months. Latter probably due to senile decay. Did not return for further test or treatment.

Mr. F. Aged 26. Hand-to-hand deflection 90 millimetres positive to 90 millimetres negative. Changed his mind several times before submitting to even hand-to-hand test. Promised to wear appliance, and afterwards admitted that he left it off the next day.

These cases may not be considered to be conclusive; but with many other observations to guide me, I have no doubt that what I have said is, in the main, correct.

Epilepsy.

It follows as a matter of course that anyone engaged in electro-pathological research would bestow a great deal of attention upon this awful scourge of humanity, and I have been fortunate enough to have had many opportunities of studying it. My remarks, however, are strictly confined to the neuro-electrical problem presented by the disorder, and even from this comparatively narrow point of view it exhibits so many complex features that I am quite at a loss for an opinion of its origin, or of the predisposing causes. I know what happens, but how or why it happens is hidden from me, though it will certainly be revealed to some other student, and in this connection it is my earnest hope that the data obtained by me may prove to be of some value. Dr. Bowman suggests that a possible explanation may be found in the fact that the high-resistance albumen in the blood coagulates in some individuals at a comparatively low temperature, and this theory certainly merits consideration.

The principal neuro-electrical phenomena presented by epilepsy are low body deflections combined with a sub-normal body temperature, excessively high head deflections and temperature, and a point of least resistance at some part of the skull, from which, during an aura or during and after a fit, an abnormally high deflection is obtained.

If we compared by means of comparative deflections a healthy person A. with an epileptic subject B. we should obtain the following approximate data:—

A. Temperature normal. Hand-to-hand deflection, 250 millimetres (say) positive. Head deflections, varying round 270 millimetres. Above navel, 200 millimetres; spinal cord, 240 to 200 millimetres.

B. Temperature, 95·6° F. Hand-to-hand deflections, 120 millimetres (positive or negative). Head deflections during an aura or fit, or after a fit, 700 millimetres (shunted down). Above navel, 10 millimetres; spinal cord 10 millimetres (more or less). Point of least resistance in skull, 1200 millimetres (shunted down to scale limit).

The direct cause of the fit is in fact a species of neuro-electrical brain storm, and this storm is due to the nerve energy generated in the brain not being able to find its proper outlets or channels from the brain to the nervous system, with the result that the neuro-electrical pressure in the brain becomes unbearable, and produces a fit. Were this pressure not relieved death or insanity would probably ensue, but Nature provides for this contingency by creating a path of least resistance to the passage of the current of air somewhere in the skull. The exact spot must be tested for, and found in each case, and it is from this spot—a safety valve—that the highest head deflection is obtained.

Too much importance can hardly be attached to the existence of this "safety valve," because it not only points to a means of alleviating the disorder, but affords strong proof of the soundness of the theory I have advanced.

We have in this supposititious case of B. low body deflections and temperature, and high head deflections and temperature, and any curative measure or means of relief should have the effect—I should like to say the immediate effect—of increasing the body deflections and temperature, and decreasing the head deflections and temperature. Now bromide does not do this. It acts by checking the generation of nerve force in much the same way that it acts in photography by checking development.

There is, however, a way of giving immediate relief, and of, I feel assured, preventing to some extent a recurrence of the disorder, and that is by shunting nerve current from the head to the body.

If the hair covering the "safety valve" is removed, and a small silver plate fastened upon it by means of, for example, adhesive plaster, and an elastic belt carrying a circular silver plate provided with a terminal is placed round the waist in such manner that the body plate makes contact with the skin, preferably just above the navel, and both plates are connected by a wire of low resistance, the deflections and temperatures will, in the course of a few minutes, go to normal.

There is also at least one other proof. If the patient is watched and an aura detected no fit will ensue if the head is at once wetted with hot salt water, to decrease the skin resistance and so provide what we may term an artificial passage to air for the congested neuro-electrical current.

Whatever the cure may eventually prove to be, it must, as one of its curative properties, have the effect of preventing the brain from becoming neuro-electrically congested, and the body neuro-electrically starved. Cure is essentially a matter for the physician, and not for the electrician, who can do little more than to describe, within the limits of his knowledge, the electro-pathological features of the disorder for the guidance of his fellow scientist. One other suggestion may, however, be made, and that is to forbid the use of hair pomades and oils, and above all of peroxide of hydrogen, as these one and all assist in bringing about the congestion to which I have referred.

There is also one other observation I should like to make, and that is upon the subject of the recurrence of fits. It is often said of a patient that he or she had several fits during the night, or during some few hours of the day. That, of course, is not true. It would be the same fit, and its intermittency is due to the "safety valve" acting only at a certain pressure and the contributory causes of the congestion continuing to exist. If we assume the pressure required to be equivalent to 1200 millimetres, it would fall, after the safety valve had opened, to, say, 500 millimetres by reason of the rush of current to air. But with the closing of the valve the pressure would again mount until it again reached 1200 millimetres, and so on, until the contributory causes ceased to exist.

I will now give a brief account of some actual cases. Mrs. S. Aged 45 years. Fits commenced when she was between 17 and 18. She was better during the twelve months of her married life. Was under hospital treatment (bromide) at the age of 30, and also at 38 (bromide). Had not had a very bad fit for 16 years, but had had three (?) attacks about a fortnight before coming to me. Complained of great loss of memory.

Temperature (body), 95·5° F.; hand-to-hand deflection, 115 millimetres positive; body deflections, all low. Found point of least resistance about 2 inches above the middle of the left ear. Points of highest resistance, right lobe of brain and back of head to a point slightly to the left of the spinal column. Experienced a faint feeling in the region of the solar plexus before an aura.

We then fitted a silver plate to the point of least resistance, and a body plate such as I have described, and connected them by means of a flexible copper wire.

The deflections in temperature before connecting, and six minutes after, were as follows :—

BEFORE.	AFTER.
Temperature of body 95·5° F. -	98·4° F.
Hand-to-hand ϕ, 115 m/m positive	265 m/m positive.
Body deflections, lower than above-	comparing with above.
Head deflections, off scale - -	" " "

Mr. "B." Aged 30. This patient was brought to me for testing purposes only, but I quote the case because he experienced more than one aura whilst with me, but the prompt application of hot salt water to the head instantly dissipated the congestion. He had been afflicted for twenty years and had been treated (bromide) at two hospitals.

I found a low body temperature, low hand-to-hand deflections, a deficiency of current in the region of the solar plexus and along the left side and back of cranium very high head deflections, and the point of least resistance to the right front of the cranium. All the data were confirmatory.

The following case is, I venture to think, even more instructive than the first :—

Master "S." Aged 16 years. Duration of disorder 8 years. After he was 7 years of age the fits became fairly frequent, but he could walk and, apart from the epileptic condition, appeared to be in a normal state of health. He went into ——— Hospital, and after remaining there for three weeks was discharged with advice to keep on a low diet. He afterwards gradually got worse, the fits became more severe, and he began to lose the use of his limbs. When between 10 and 11 years of age he entered the ——— Hospital, where he remained for three months without improvement. After that he was an out-patient for some two years, during which time he was given bromide and steel. Since then he had constantly been under medical treatment—the bromide being continued and had become steadily worse; had lost all power of speech and the use of his limbs, as well as control over his motions and urine.

I carefully examined (galvanometrically) the whole of his body, finding subnormal temperature and deflections everywhere except in one part of the head, which, however, at the time of testing, presented the unusual feature of low deflections (12 millimetres only), except at the point of least resistance (in this instance in the exact centre of the cranium), which gave 300 millimetres. The patient seemed dazed. His right hand was twisted, while the left hand clutched the breast. The feet were twisted and arched, the lips pale and the mouth firmly closed.

At the request of his father I did all within my power to give relief by shunting the nerve current from the point of least resistance to the body, and stopped the bromide for the time being.

Under bromide the average number of fits per diem was four to five, with convulsions. On reference to my diary I find that the shunting connection was made on October 17th. From that date until the 21st there were two fits, both in the early morning. The following are the entries in my diary :—

Oct. 21st. Passed good night.

22nd. One fit at 11 a.m., and one at 5.30 p.m.

23rd. Passed good night. Slight fit in afternoon.

24th. Bad night. One fit at 4, and another at 7 a.m.; three during day.

25th. Good night and day. No fit up to 8.45 p.m. General symptons improved. Limbs better. Intelligence more alert.

26th. Passed fair night. No further fits. Slight convulsion at 8 a.m. (after disconnection shunt plates all night), lasting only a few seconds. Very slight fit at noon.

27th. Slight fit at 2 p.m. Another (more severe) at midnight after shunt plates had been disconnected for four hours.

28th. Very slight fit at 10 a.m., before shunt plates were connected. Aspect more cheerful.

29th. One fit of three minutes' duration at 10 a.m. *Note.*—It was most difficult to keep the head plate in position.

30th. Good night. One slight fit in morning.

31st. Continued tranquil. As back (body) contact plate was liable to come off, fitted a firmer one. During removal of appliance there was a slight fit, which immediately subsided upon contact being restored.

Nov. 1st. 8 p.m. Had passed a somewhat restless night owing to constipation, but had had no fit all day. Appeared brighter and more intelligent and the body temperature was higher; mouth not so obstinately shut.

2nd. Been perfectly tranquil all day. Head very hot to the hand. Examined head plate and found it in wrong position. Readjusted it, when head became quite cool and restlessness ceased. Temperature almost normal. Improvement maintained.

4th. Had three fits yesterday. No motion since the 1st. Both contacts loose. Head hot, hands cold. Readjusted contacts, when head cooled at once.

Note.—On the following day I asked Dr. J. Gowing

Middleton to thoroughly examine the patient. He pronounced the case to be one of arrested mental development—epilepsy being concurrent—and quite hopeless. He advised the continuance of my treatment, but as the parents were obviously unable to carry out my instructions, and I could not spare the time required, there was no course open to me but to abandon the case. To a certain extent, therefore, the results were negative, but while I do not lay undue stress upon it, there can be no doubt that the patient derived benefit from the treatment, such as it was. Taking the average number of severe fits under bromide, he should have had at least seventy-six from October 21st to November 4th, whereas—without bromide—he had seventeen only, and nearly all of these were very slight.

Cancer.

Notwithstanding the fact that many hundreds of the most notable men of their day have devoted their lives to the study of cancer, it is unfortunately true that the *fons et origo* of the disease still remain in obscurity. Cancer has yielded nothing decisive to bacteriological research. Surgery cannot claim that the knife is an infallible cure, electro-cautery has proved to be merely useful, and medicine has not been able to provide more than temporary relief from pain. From galvanometric research also nothing decisive has been learned, but I am encouraged to hope that this is because the opportunities of observation and study have been too few in number, and that the little we have gained will at all events stimulate other physiologists to renewed investigation upon the lines I have ventured to lay down.

Of cases of suspected cancer I have tested perhaps a dozen, but of cancer without doubt, of cases not only pronounced to be cancer but which were to be operated upon a few days after galvanometric examination, I have had two only, and of these I propose to give full details.

Mr. C. Aged 50. Cancer of the throat. Temperature subnormal. Hand-to-hand deflection 15 millimetres negative veering very slowly to 88 millimetres positive. General neüro-electrical condition very low and unsatisfactory.

The cancerous growth was of the size and shape of an egg on the right side of the throat, and pressing upon the larynx, while the secondary deposits were exhibited in a larger protuberance extending from the cancer to the right

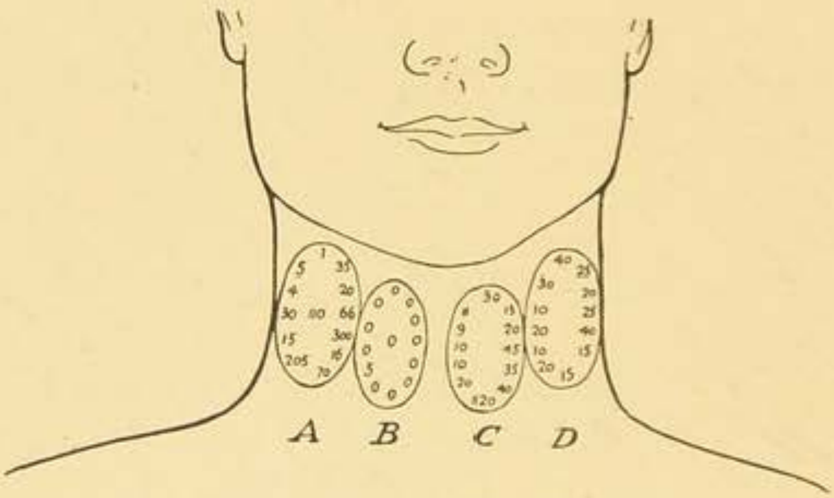


FIG. 14.—Cancer in Neck.

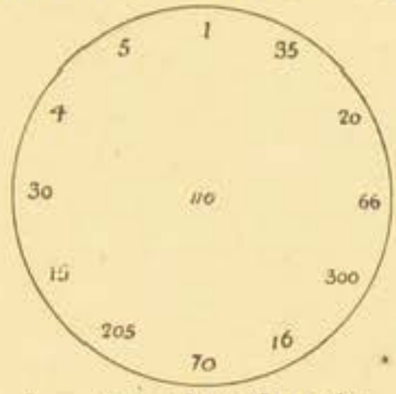
side of the neck. I made careful drawings upon the throat and neck (on both sides) with a brush and water-colour, so that the areas of cancer and secondary deposits were reproduced on the unaffected as well as on the affected side of the throat and neck (see Fig. 14), and took what I call the "clock test," *i.e.*, making one contact in the centre and the others in accordance with the hours upon the dial of a clock. The deflections were of course in millimetres of the scale, and were comparative only; that is to say, no value in fractions of a unit was given to them.

A = The area of the secondary deposits.

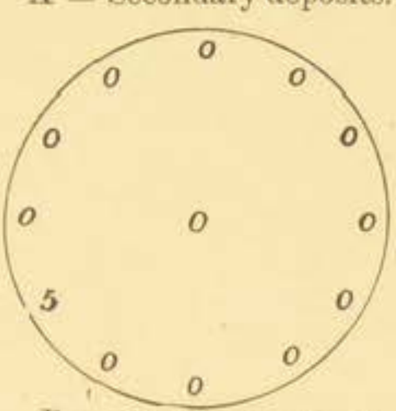
B = The cancerous growth.

C = An area on the unaffected side corresponding to the cancerous growth, and

D = An area on the unaffected side corresponding to the secondary deposits.



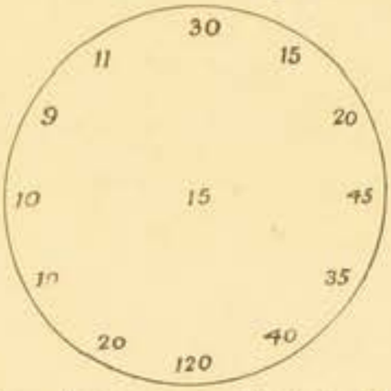
A = Secondary deposits.



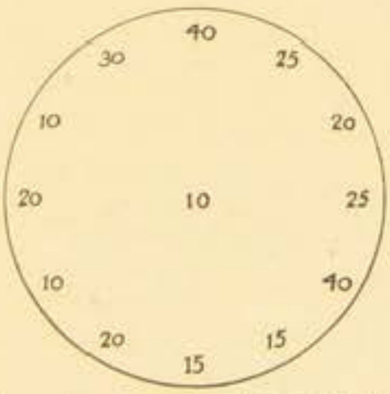
B = Cancerous growth.

A gave the following deflections, taking the numbers 1 to 12, as the hours on a dial.

With the exception of the 120 millimetres at what we may call 6 o'clock on C, most of the deflections from C and D are consistent with the hand-to-hand deflections of the patient. The cancerous growth itself, however, is apparently dielectric in character, interposing a very high resistance to the passage of neuro-electricity through it, or being in all probability an absolute non-conductor. In A the hours 10, 11, and 12 are suggestive of a cancerous condition, while the higher deflections at 4 and 7 may be due to the presence at those points of septic matter. But however that may be, this suggestion occurs to my mind: If *we can establish beyond any reasonable doubt that an absence of*



C = Area, on unaffected side, of B.



D = Area, on unaffected side, of A.

conductivity is a condition peculiar to cancer we have at least discovered an infallible means of detecting its presence; possibly in time for curative measures to be effectually adopted. Not only is that so, but its area could be determined with exactitude and a drawing made upon the skin for the guidance of the surgeon.

As an illustration of my meaning let us take a supposititious case of cancer of the breast in which operation is necessary. The area of the cancer as determined by present methods is, let us say, as shown by Fig. 15.

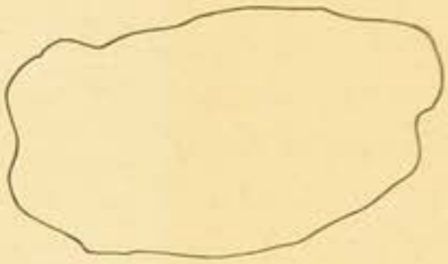


FIG. 15.—Area of Cancer by Ordinary Diagnosis.

But its area as shown by the galvanometer would be

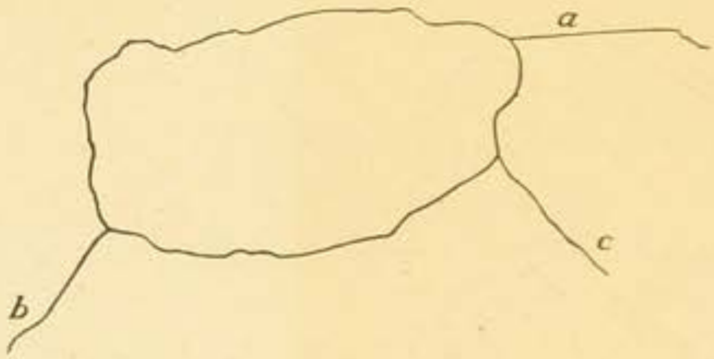


FIG. 16.—Area of Cancer by Electro-Diagnosis.

Operation as performed by the surgeon would remove the cancer shown by Fig. 15, but since the existence of threads *a*, *b* and *c* in Fig. 16 was not detected, *they* would remain, to bring about, in all probability, a recurrence of the disease at some later period.

Let us now carefully consider the second case, and see if it agrees in every respect with the first.

Mrs. D. Aged 49. Cancer in breast for four or five years. Cancer in neck for five or six months. Discharged from three hospitals as incurable. Temperature 94·5°. Hand-to-hand deflection 195 millimetres negative.

As in the previous case we made careful drawings, to measurement, upon the skin of the affected areas, and of areas corresponding to them upon the unaffected side, and repeated the "clock" test with the following result.

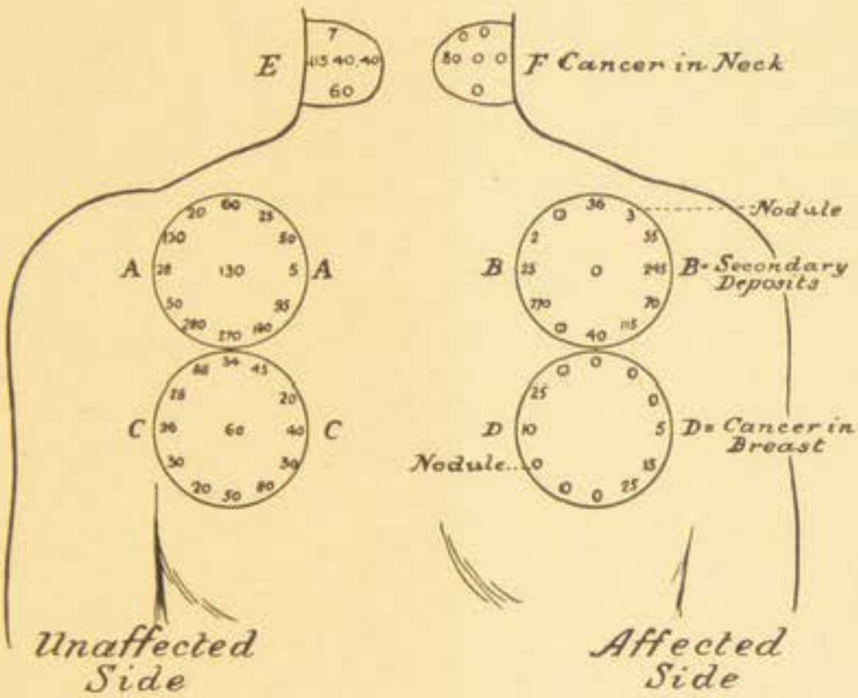


FIG. 17.—Cancer in Neck and Breast.

Here we have a similar, if not precisely similar, electrical condition, with the exception of septic matter (if the high deflections are caused by inflammatory septic matter), invading A at points 5, 6 and 7 (analogous to B at points 3 and 7), while the other deflections on the unaffected side are what might be looked for from the hand-to-hand deflection. Another interesting feature is the line of cancer from D through B to F, or *vice versâ*.

Some Diseases of the Ear.

As a great many people apart from members of the medical profession are interested in the subject of deafness, I venture to offer a view of this natural telephone system in language understandable by the lay mind.

Anatomically described the middle ear is an irregular cavity, compressed from without inwards, and situated

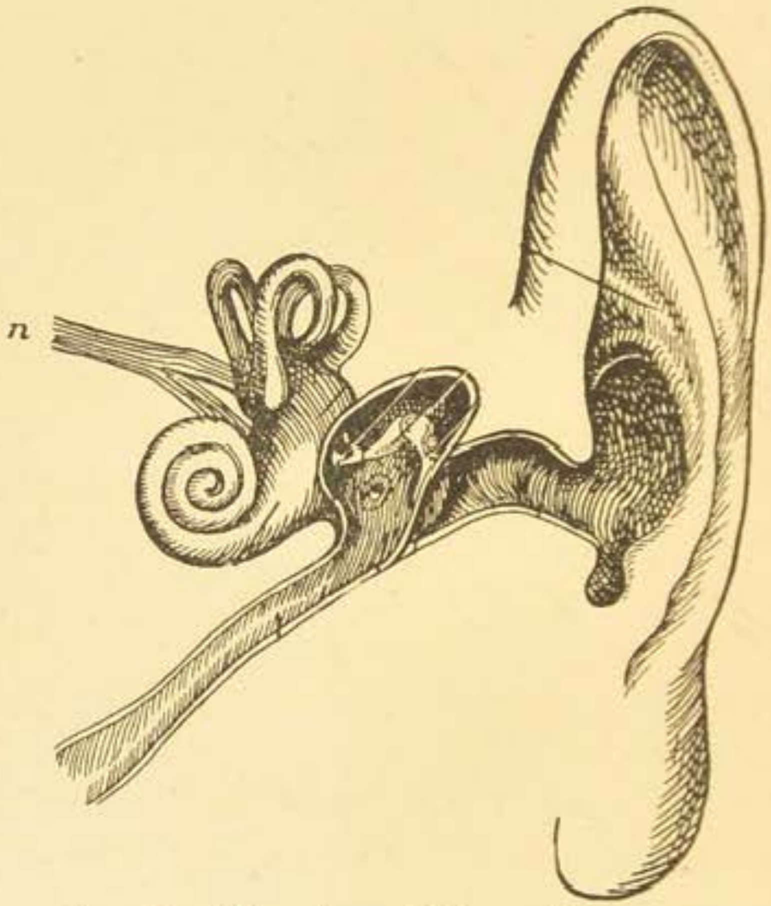


Fig. 18.—The outer, middle, and inner ear.

within the petrous bone. It is placed above the jugular fossa, the carotid canal lying in front, the mastoid cells behind, and the labyrinth internally. It is filled with air, and communicates with the pharynx by the Eustachian tube. The tympanum is traversed by a chain of movable bones, which connect the membrana tympani with the labyrinth (inner ear) and serve to convey the vibrations communicated to the membrana tympani across the cavity of the tympanum to the internal ear.

But let me put it another way—looking at it from an electrician's point of view—and call the outer ear, as far as the drum, the receiver; the middle ear, the microphone; and the inner ear the line wire to the brain of, as I have said, a natural telephone system.

We must remember that the middle ear contains a chain of movable bones, and that upon their freedom to vibrate the efficiency of the microphone depends. One of these bones rests against what is vulgarly called the drum of the ear, another against the line wire, and between them is a third bone assisting in the transmission to the line wire of the vibrations received by the drum and intensified by the microphone. Furthermore, we must bear in mind that nerves of special sense serve the ears, and that these nerves only convey messages *to* the brain.

At least three faults susceptible to treatment are possible :—

1. The drum of the ear may be thickened.
2. The bones of the middle ear may be clogged by catarrh or urates so that they are not free to vibrate; or
3. The auditory nerve (the line wire) may be faulty.

In either case the vibrations do not reach the brain unimpaired because—

1. They are partly or wholly stopped or rendered "woolly" by the drum.
2. If responded to by the drum they fail to set fully in motion the clogged bones of the middle ear or at all; or
3. The faulty line wire fails to carry them fully, or at all, to the brain.

But there is a further source of trouble. Sometimes the patient is so run down that the vital energy is at a low ebb. Then it is that the "weak spot" suffers, and it not infrequently happens that deafness results from this cause alone. In all probability the nerves of special sense are "closed circuits" requiring a given supply of neuro-electricity and becoming disorganised when that supply falls below a certain pressure.

We have then four faulty conditions--apart from perforation—to deal with, and when one of these faulty conditions occur the telephone system must be tested and the nature and locality of the fault ascertained.

If the drum is thickened, or the tube of the outer ear swollen by rheumatoid arthritis or other causes contributory to inflammation, it will yield an abnormal deflection, so will the middle ear, tested from outside the mastoid process, if it is catarrhal, or give a subnormal deflection when the bones are, and have been for some time, clogged with urates; while the inner ear (the line wire) can be made in the same way to disclose its degree of conductivity by giving the measure of the nerve current in it as compared with the nerve current present in the auditory nerve of a healthy person of similar hand-to-hand deflection. If it is partially atrophied the first step should, I think, be to restore it to its normal condition of an active closed circuit.

In the case of catarrh of the middle ear, or of the presence of hardened catarrhal matter in the middle ear, the principal difficulty is of course to introduce a remedy or a solvent into what is practically a closed cavity. But it may be done. A fluid of high electrical resistance and great penetrative power will, when applied to the outside of the mastoid process, go right through the petrous bone, and not only allay inflammation, but, as experience has shown, frequently dissolve the film or films clogging or preventing articulation.

When the disorder is produced by urates in the middle ear, the question becomes, to my way of thinking, whether by similar endosmose or by electrical action, a solvent of uric acid, such as a solution of thyminic acid, cannot be introduced.

I will now give a few cases to illustrate the various faults I have mentioned, or some of them :—

Mrs. G. Aged 63. Deaf since early childhood. Left drum perforated. Right thickened. Loud noises in left ear and right side of head. Rheumatoid arthritis hereditary. Had neuritis some five years before, and disease since become chronic. Patient used large ear trumpet, left ear only. Had not heard with right ear for sixty years.

Upon testing we found that the left outer and middle ears (she was wearing an artificial tympanum) were inflammatory; giving very high deflections, while the right outer ear was very little better. The right middle ear, however, did not exhibit a high deflection, and observing that rheumatoid arthritis was more or less general I formed the opinion that by reason of an internal swelling caused by that disease, the "receiver" was not conveying vibrations to the middle ear or microphone.

To test this theory we plugged the left ear with cotton wool and filled the right ear with a dielectric fluid. In forty-five minutes the fluid was wiped from the ear and the patient heard with the right ear (without the trumpet) for the first time for sixty years. Finally the left ear was treated for inflammation, and its use forbidden. Many months afterwards the patient's condition was said to be in every way satisfactory.

Mrs. W. Aged 35. Totally deaf left ear; thickening of drum of right ear. Noises right side of head. Had been so for some years. No cause assigned; no medical opinion given. The hand-to-hand deflection was satisfactory but both middle ears gave high (inflammatory) readings; the left especially so. We applied the same fluid as in the previous case both externally and internally to the left ear for half an hour, at the end of which time the patient could hear quite well.

The internal application was made by filling the outer ear with the fluid, and plugging it with cotton wool, while the outward application was made by soaking a pad of wool with the fluid and placing it over the mastoid process while the patient remained in a reclining position upon her right side. This was a fault in the "microphone."

Mrs. C. Aged 62. Patient very deaf; both ears. Used a large ear trumpet, and even then heard with difficulty. Had suffered much from fever and neuritis. Her hand-to-hand deflection was not more than 25 millimetres, falling almost to zero, but all the deflections from the ears and the cranium as near as we could get to the auditory nerves were consistent with the general electrical condition, and it seemed probable that there was a deficiency of nerve energy in both closed circuits (auditory nerves) and that the faults were, in short, in the "line" wires. We therefore applied a weak continuous current to her body to raise her hand-to-hand deflection to 270 millimetres positive, and her hearing was immediately restored. That was some years ago and so far as I am aware her hearing has continued to be normal except during exhaustion consequent upon a severe attack of neuritis. This was a fault in the line wires.

Mrs. J. Aged 30. Deaf right ear. Hand-to-hand deflection very low and unsatisfactory. Ear deflections consistent. Treatment as in the last case effected great improvement in fifteen minutes. Did not hear from her again, but as she from time to time recommended other patients one can reasonably assume she was benefited.

THE ELECTRICAL RESPONSE OF THE LIVING AND NON-LIVING.

In a previous part of this work I have laid stress upon the ascertained facts that neuro-electricity is chemically generated within the body, and that disease not only affects that generation, but, by altering the resistance of the conductors, changes the quantity of current flowing through a part or parts of the human circuit.

Now there is an essential difference between the electrical response given by the living and the non-living. We have seen that if the right hand is connected by means of a suitably insulated wire to one terminal of the galvanometer, and the left hand is similarly connected to another terminal, a current will pass through the coils of the recording instrument and cause a deflection, the strength and sign of which are in accordance with the neuro-electrical strength and temperament of the subject. But that is not all. There is another factor of great importance and that is, that *if the right hand, as a whole, be positive and the left hand negative, the right thumb will be positive and the four fingers of the right hand negative, while the four fingers of the left hand will be positive and the left thumb negative*, the thumb in each case carrying a greater quantity of current.

With the extremely sensitive instrument at our command we could, without any shadow of doubt, ascertain whether life had really departed from a body.

If we took, for example, two very fine steel needles and connected them by flexible wires to the galvanometer we should, if we inserted those needles beneath the skin of the thumb and fingers of each hand, obtain, during life, a *reversal of sign*. I have no hesitation in saying that if any such reversal was perceived *life must still exist*. If, however, life had absolutely departed the body would merely have capacity or power of absorption of outside electricity, as a sponge has of water, and whilst a deflection would be obtained, that deflection would be governed entirely by the electrical sign of the air of the room in which the body lay, *and would be unchangeable*, no matter where the contact happened to be made.

This law applies to the non-living generally, no matter whether it be the human body, an animal, a tree, a plant, a vegetable, a fruit, or a tuber, etc. All things that are moist possess this power of absorption of electricity, but only the living have an electrical system, and positive or negative plates or terminals.

It has often been said that "electricity is life." Qualify the statement somewhat and say that nerve energy which resembles electricity, is vitality, and I agree, because we always find that a high standard of nerve force, or a high neuro-electrical potential, and mental and physical vigour are synonymous terms. It is true that temperament plays an important part, and it does not always follow that a negative deflection argues want of mental or physical activity, but once the normal potential of an individual has been determined, any diminution of that potential must necessarily be accompanied by a diminution of strength, either physical or mental or both.

Another thing to which I should like to call attention is that during the early hours of the morning vitality is, as we well know, at its lowest ebb. I have made many tests of the generation of the natural human current during sleep, and have invariably found that at about 3.30 a.m. it is at its lowest point; the fall being from about 250 millimetres to 45 millimetres.

It has often suggested itself to me, and indeed I have put it into practice with excellent results, that if a low neuro-electrical condition is coincident with a low physical condition one should be able by restoring the neuro-electrical condition to normality to do something towards restoring the physical condition of normality.

To make my meaning clear, it not infrequently happens that the state of a patient is anxiously watched between the hours of 3 and 6 a.m., and that brandy is kept in readiness for administration in case of need. But brandy, although of great value at such times, is a dangerous stimulant, and is evanescent in its beneficial effect. If the patient could be tested at the moment of collapse it would be seen that the deflection had fallen to a very low figure of the scale (3 or 4 millimetres), and that the administration of brandy had, for the time being (that is to say for half an hour or so), considerably increased it. But there is another, and a better way out of the difficulty, and one which, in the great majority of cases, might effectively prevent any unfavourable symptoms. That way is to attach a couple of flexible wires, bared for about two feet of their length, to the wrists of the patient, connecting the other ends to a small dry cell which could conveniently be placed under the pillow. This would charge the storage cells of the body and keep them charged throughout the night, maintaining the deflection at a point consistent with health and doing nothing prejudicial as an artificial stimulant.

Some Forms of Death.

I have also often thought that we sometimes accept the supposed visitation of death too readily. It is, of course, irremediable when its direct cause is syncope from extreme exhaustion, from septic poisoning, or from some internal rupture or organic trouble. But now and again death comes to those who, apart from the direct cause, are in good health. We hear of shocks of various kinds under which the sufferer succumbs, of people being frozen, or of falling down suddenly from some alleged "stroke."

It is evident that where excessive weakness accompanies the final collapse any attempt to restore animation must be attended by failure, if only for the reason that there would be a practically instantaneous relapse. But in other cases we should not, in my judgment, accept death as fact without making some attempt to restart the heart's action.

The heart is nothing but a pump, and the circulation of the blood is essential to life. In apparent death from drowning many methods of artificial respiration and inspiration are resorted to, and even in cases where there has been no perceptible action of the heart or lungs those who have practised Sylvester's or Howard's methods of restoring animation have persisted in hope until their efforts have extended over some eight or ten hours.

I do not say that in cases other than of drowning it is possible to restore animation, but I do not see why not, and certainly think that some effort should be made in that direction.

There are, I believe, many authenticated cases of premature burial each year.

Conclusion.

If anything I have said appears to be in any way boastful let me say at once that I regard the discoveries I have been permitted to make from a purely impersonal standpoint, and without any consciousness of self-appreciation. I can, in fact, only wonder that it has remained for so obscure a person as myself to direct attention to such obvious truths; while if there appears to be anything marvellous in the curative measures I have adopted, a little reflection will show that they are simple measures which must have suggested themselves to any electrician conversant with the class of work to which I have been accustomed.

There is, however, one reason for wonder, for astonishment so deep as to close the door, as it were, to possible explanation, and that is "why and how it is we have been left so long in ignorance."

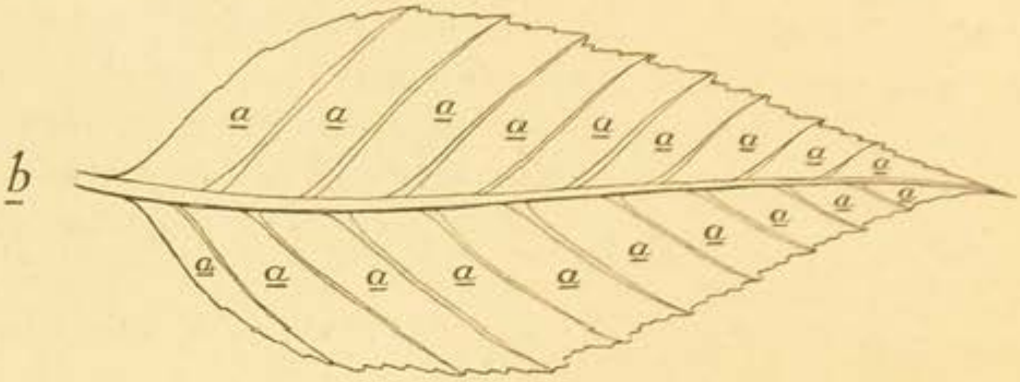
APPENDIX.

The Coincidence of Negative Deflections with some Vegetable Poisons.

In order to render these observations intelligible I must trespass to some extent upon the field of vegetable electrology.

The earth and the air (except possibly during heavy rain or while some electrical atmospheric disturbance exists) are respectively the negative and positive terminals of Nature's electrical battery, so to speak. Everything that grows in the earth is negatively charged through the roots to the sap, and by means of the sap to the veins of every leaf, etc., while the foliage between the veins is positively charged. In the same way fruits receive their electricity; the apple, for example, is negative from the stalk to and including the core, the pulp is positive, and the outer rind an insulating covering designed to conserve the energy of the cell.

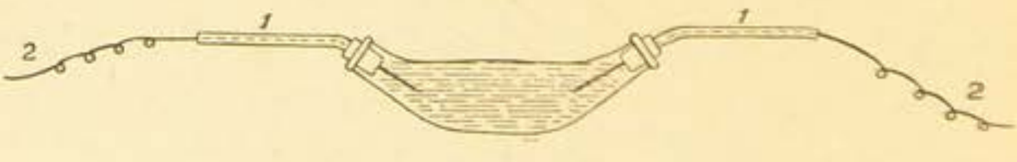
We are taught by what is called instinct to reject as food that which is negatively charged, or is merely insulating material. We do not eat the core of an apple or pear, the stalk of a cabbage, the rind or pith of an orange, or the skin of a peach; and if roots are used for human consumption it is generally because they are supposed to possess some medicinal value. I believe that I am right in saying that most, if not all, vegetable poisons are extracted from some negatively charged part of the plant, and not from any part of the leaf marked *a* in the illustration, which latter would be positively charged.



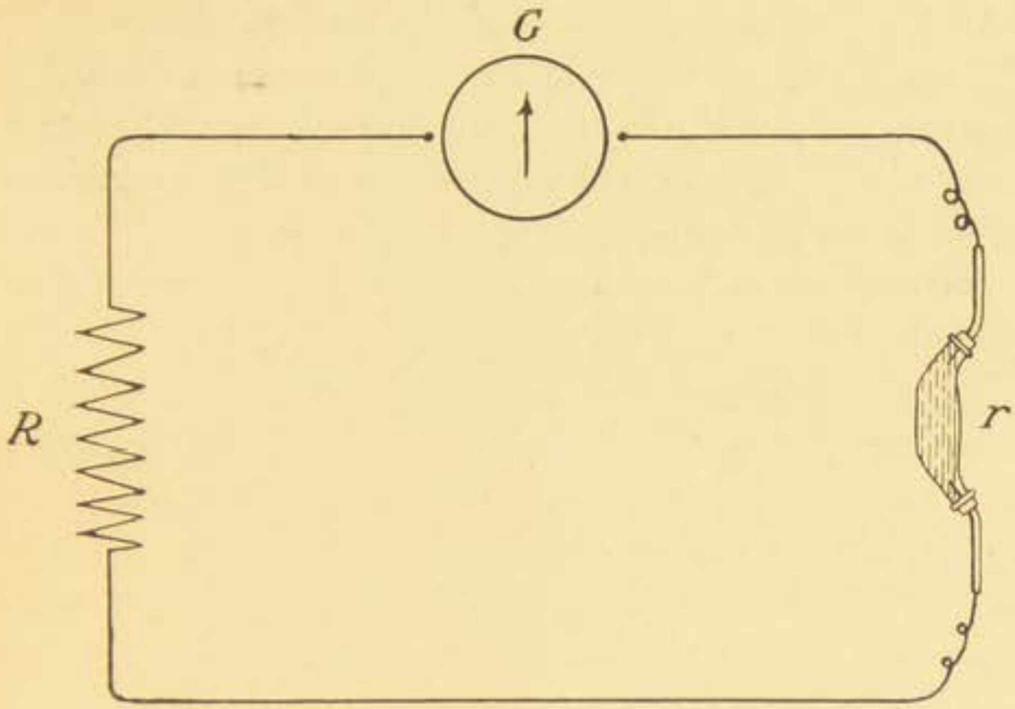
The stalk *b* would be the negative terminal, and each part *a* a positive terminal of the leaf.

The idea occurred to me to see whether certain vegetable poisons gave a negative or a positive deflection. Theoretically they should all yield a negative reaction, and I should, had the opportunity occurred, have tried to verify or disprove this. But other work rendering this impossible, we took two things largely consumed by man, *i.e.*, tea and tobacco, and after first ascertaining the electromotive force and sign of the air of the testing room, proceeded to conduct the following experiments. First we prepared a very strong infusion of tea which, in order to obtain the tannin, we allowed to stand for some hours and get cold, and also boiled two ounces of shag tobacco for one hour and let it stand for three hours.

The liquids to be examined were contained in two double-ended 8-ounce feeding bottles, the corks being drilled to receive thick copper wires, insulated with gutta-percha except where bared for purposes of contact, thus:—



1 and 1 = contact wires. 2 and 2 = connecting wires to circuit shown in the next figure.



R = variable resistance = 9,990 ohms.
r = liquid under examination.
G = the galvanometer.

The actual resistance in ohms of r was not calculated. The bottles, corks, and electrodes were new and used for the first time. We will call the deflection given in each test, D.

TEA. Upon connecting the bottle containing the tea $D = 238$ millimetres negative, mounting slowly.

As the infusion was not quite cold we left it with the connections unaltered for three hours, at the expiration of which time D was violently negative (rushing back with extreme rapidity on breaking and making contact) at 225 millimetres; probably more tannic acid was set free. This test repeated many times gave the same result.

TOBACCO WATER. The immediate D with cold solution was violently negative, and it remained so for several hours, when it was left until the following morning with the bottle tightly corked.

At 5 a.m. the deflection had declined to zero, and at 8.30 a.m. had risen slowly to 130 millimetres positive. We then removed and cleaned both electrodes, giving the air free access to both ends of the container and thus practically restoring the solution—from the electrical point of view—to its original state. This was at 2.30 p.m., when $D =$ 230 millimetres negative : steady.

Now the air of the testing room was positively charged, and therefore exposure to that air would tend to positively charge the liquid. It would seem, therefore, that the earlier exclusion of the air had temporarily nullified the toxin, and further, it appears to be probable that the negative effect does not, in this case, increase with time. If we assume that the harmfulness of the solutions was in proportion to the strength of the negative deflection, the tea undoubtedly became more injurious and the tobacco water less injurious the longer each was allowed to stand.

The Generation of Neuro-Electricity during Sleep.

As I attached great importance to this experiment, every care was taken to ensure correct readings. The insulation of the room and instruments was perfect and the conditions remained unaltered throughout the duration of the test.

The subject was a healthy boy of 9 years of age, and after any static or induced charge had been dissipated a wrist-to-wrist deflection was carefully taken at 7.50 p.m. and found to be 98 millimetres positive : the comparatively low electromotive force being due to the fact that contact with a main conductor was not made.

The object of the experiment was to determine what difference, if any, in the generation of neuro-electricity was made by unconsciousness and absence of motion ; the first with a view to obtaining data bearing upon the functions of mind in this connection, and the second to see to what extent motion governed the deflections.

Accurate observation was therefore necessary at such times when the subject was both sound asleep and absolutely motionless, and only at such times were the deflections recorded.

The results went to show that generation is lessened during sleep, that it is further decreased by a subnormal temperature, and that movement of a limb or limbs momentarily increases the potential. I am by no means sure, however, that the latter can be ascribed in its entirety to static electricity set up by muscular contraction. Although that may happen, I think that in all probability it is due to a set or sets of ganglion cells being brought into action and made to discharge by muscular contraction.

The fall observed was from 98 millimetres positive to 70 millimetres positive while the temperature was normal, but upon the body becoming cold the deflection fell to 35 millimetres positive at 2.30 a.m., and did not reach 50 millimetres until half an hour later.

INDEX—GLOSSARY

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