Matter and Force considered in relation to Mental and Cerebral Phenomena. By J. Thompson Dickson, M.A., M.B. Cantab., M.R.C.P., Resident Medical Superintendent of St. Luke's Hospital.

Well sang the Psalmist: "If I take the wings of the morning and dwell in the uttermost parts of the universe, God is there." Thou too, O cultivated reader, who too probably art no Psalmist, but a Prosaist, knowing God only by tradition, knowest thou any corner of the world where at least *Force* is not? The drop which thou shakest from thy wet hand, rests not when it falls, but to-morrow thou findest it swept away; already on the wings of the north wind it is nearing the Tropic of Cancer. How came it to evaporate and not lie motionless? Thinkest thou there is aught motionless; without force, and utterly dead?

Sartor Resartus.

The substance of the following paper was in March last read before the Medical Society of London. Its subject is a consideration of the molecular changes the brain undergoes in the production of mental impression; the Potentiality of the vitality of the brain; and the physiological process by which affirmation or negation of idea about idea, or that process which we call reasoning, occurs. Its object is the attainment of a comprehensive view of cerebral phenomena under normal conditions. Its practical bearing is upon that class of diseases which we call subjective. In entering upon such a discussion I doubt not I may be met with an objection on the score of the apparent impossibility, in the present state of our knowledge, of determining any change at all in an organ we cannot to any extent see, still less examine, during the life of the individual. I will, therefore, at once answer that I purpose drawing my conclusions by simple induction from facts that are daily before us; and since exception may be taken to some of the terms employed, I will commence by defining those which are important, as far as their precise meaning has any significance in this paper, and illustrating the definitions, so far as illustration may serve to make more clear the idea intended to be conveyed.

Much that I may state as fact will of necessity be not new, but perfectly well known and familiar, but it is curious in how strange and new a light old facts often appear from a new point of view; while by the rearrangement of our mate-

rials for induction, startling and unexpected conclusions may not infrequently be arrived at.

The term *Force* we understand to express that physical property in a body which separates its atoms. Force may produce action or visible motion in another body or may counteract such action—in other words Force is a term applicable to any mode of motion. Force has an existence *in potentiâ* in everything that is visible or tangible.

Matter.—By the term matter we are to understand not only a mass of material but the simple elementary substance of which everything that is visible or tangible is composed.

We can best appreciate matter as particles or atoms held together in certain relations. Were there no such potentiality as *force* the condition of matter would be that of absolute mass and inertia; as it is, however, no substance is absolutely a mass, but its atoms are separated from one another in a greater or less degree. In the least condition of separation we have solids, in a separation of atoms beyond a certain degree we have that form of body which is presented to our senses as liquid, and beyond a second standard we have that separation of atoms which we recognise as aeriform or gaseous.

The relation of mass to volume is more or less the inverse of the potentiality separating the atoms. The atoms of matter are absolutely indestructible, and it may be contended that force also is not capable of annihilation, though we use the expression used up, spent, or latent, merely indicating thereby that as the matter has changed its mass or volume, so the force or motion which was the essential characteristic of that mass or volume has changed its mode.

By the term *Potentiality* I mean possibility not actuality—the quality which exists in certain bodies *in potentiâ* only—that is, having power or influence of affecting or impressing us in some measure without being actually inherent in that body; the word having the same import as in the expression potential heat or potential cold.

By the term *Motion*, I mean not that visible motion which we recognise as the resultant of two or more forces, but motion in the abstract, that abstract idea of a property which influences the atoms of matter and becomes manifest to us in various modes, as light, heat, electricity, chemical affinity, &c., all of which are correlative.

By the term *Vitality* I mean the principle of animation.* It is hardly necessary for me here to enter upon the arguments showing that the principle of animation—which, for want of a better expression, I still prefer to call Vitality—is in the abstract that same influence and principle which we have a notion of in the abstract idea of motion. I believe that this is now on all hands accepted.

Potential Energy is an expression I propose to use as synonymous with Vitality. I have already, in defining potentiality, illustrated the idea in the expression Potential cold, but since cold has no existence *per se*, unless it be accepted as the negation of heat, so in speaking of Potential heat we recognise that quality which influences the mass, and though not actually inherent yet is capable of manifestation as heat, by alteration of the arrangement of the particles or atoms of which the body is composed; this quality existing only *in potentiâ* is admitted to be motion, and *heat*, its manifestation, is called its mode. So likewise, by re-arrangement of the atoms of some forms of matter, we recognise a quality which influences the mass, though not actually inherent in it, but manifested to us as energy, which is unquestionably motion; the more certainly is it so because it is capable of conversion into, and is correlative with, all the other modes of motion with which we are acquainted. It is for this manifestation of motion I for the present retain the modal expression Vitality. Vitality or Potential energy is, therefore, not the resultant of the various physical forces operating together upon a mass or organism, but is itself a Force, operating as a force either directly as when brought to bear on any external, or indirectly as manifested in resistance when any other force is brought into antagonism with it.

The resultant of the vital with any other physical force is exhibited to us in that which we recognise as or designate a Vital Phenomenon: this may be familiarly illustrated in contraction by galvanizing a muscle.

The first point for our consideration is the process by which

* In the discussion upon my paper on Vitality considered as a Mode of Motion, read last year (1868) before the British Association at Norwich, objection was made to the use of the term vitality, on the ground that it was a word of metaphysical import, and therefore ought not to be employed in a physical enquiry. I answered then that my reason for using it was that it expressed the idea I wished to convey, and was generally understood, while physical science had not yet provided a substitute to express the idea of the principle of animation. I feel the force of the objection, yet still must give the same answer—the word is used, however, as a term expressing a mode of motion and significant only in its employment as expressing motion in the same degree as light or heat are employed to the same end.

mental impressions are formed. It is out of the province of this paper to undertake the metaphysical question as maintained by Sir William Hamilton, that "what we are conscious of is constructed out of what we are not conscious of;" suffice it to say that consciousness is not the basis of intellectual operations, though it may often be the result; and it is sufficient for our purpose to recognise with Hume, that "we are not wiser than our experience," or with Mr. Mill, "that experience is the foundation of all knowledge."

Our ideas, crude and simple, are vital phenomena the resultants of motion, communicated from our sense organs through their respective conductors or nerves, and the potential energy of certain brain cells with which those nerves communicate.

The impression of any external object upon a sense organ, whether it be audible, visual, olfactory, gustatory, or sentient, is an impression of motion which is at once conducted as a current through the nerves, as the motion of electricity through the wires of a telegraph, to certain cells in the brain. Change instantly occurs in one or more of these. It is not that it or they are simply set in vibration or motion, but the motion communicated to them is antagonised by their potential energy, the resultant being a change in the chemical and physical constitution of that cell or those cells; the chemical change being that re-arrangement of atoms which occurs in all chemical phenomena; the physical being that which in a greater or less degree stamps upon the cell or cells that which we recognise as the impression of the external object from which the motion was communicated.

A third phenomenon also obtains; the motion set up in one cell, or one particular set of cells, does not only affect that cell or that set, but is communicated to others in the immediate vicinity, inducing changes in them.

The evidence of the change in the cell resulting in the impression is conclusive from the fact of the impression remaining.

The evidence of the chemical change is conclusive also, for we obtain the material atoms in their changed form when thrown off as effete material.

The motion, inducing the impression in the cell, so changes the relations of the material atoms of that cell that we find that a substance has been formed there which was not present before. I would here note that experiment has gone to prove that the particular form of chemical change that occurs in all mental exertion is the production of certain phosphates; but

it must be remembered that this new formation is merely a change in the relation of material atoms through the using up of some of the motion that held them in their former relations: it is not adding or taking away any material, any more than the conversion of water into ice adds to or takes from the exact quantity of matter operated upon. But as the relation of the atoms has changed, so the motion, which is now greater, in possibly a calculable amount, than before the external impression was received, has also become altered in its mode, and becomes manifest as chemical force, which further on in the cycle is evidenced.

A reservation is perhaps here necessary, for it is evident that all the material atoms of a cell may become so changed that all its potential energy may be exhausted or used up, and thus no further vital phenomena be possible in it. This, in fact, would take place were it not that those changed and useless atoms are removed, and their place taken by other atoms of the same nature and property as those that constituted the cell before the change occurred. The effete material is taken up by the circulating blood, from which pabulum by the chemical phenomenon of substitution the new atoms are supplied, which replenish the cells and enable them to maintain their vital activity; the material for supply to the blood of course being derived in the periodic assimilation of nutrient matter, while the effete and useless phosphates are separated from the blood by the kidneys, and are to be found in the urine.

The evidence of the third phenomenon is perhaps not quite so demonstrable, but a little reflection will, I think, render it equally conclusive. An impression formed by the passing of a current from the periphery to the centre is immediately followed by the rousing in the mind of another or other impressions; for instance, we become sensible through our olfactory nerves of the perfume of a rose, and though we may not see or touch the flower, we directly have the impression of a rose in our minds; and as this second impression could not be called into prominence without some communication more or less direct, and as we admit that it has immediate association with the antecedent, and also that no communication can be made without the expenditure of motion—we have sufficient reason for the conclusion that motion has been communicated from the cell or cells set in activity in the reception of the first impression.

If now we accept as fact the theory of motion in its relation to vital phenomena, and the changes in the brain cells, the

result of the influence of motion, as above stated, we can analyse some of the phenomena of mind in relation to their production.

The simplest of all mental phenomena is that of simple apprehension, and next to this, and associated with it, is memory; while judgment and reasoning are entirely dependent upon the perfection of those so called attributes.

Simple apprehension we have witnessed in the production of a simple impression: we see a rose, and we become conscious of its existence; its image fades from mental view, and we are occupied with other objects and thoughts, but the image is not lost, the impression made on a cell remains, the cell is permanently changed, and continues in its new condition as long as it is healthy and intact.

How inappreciable is that change when the brain has again become quiescent, yet how slight a disturbance will again render it prominent. We live with our impressions in calm apathetic oblivion, till the equilibrium of the cells bearing them is again disturbed, their variations are then apparent, their spectra again come into mental view. One cell differs by comparison from another, and we appreciate the difference; in other words, we are conscious, but consciousness means only this appreciation of difference of one cell from its fellows; this activity, however, can only occur through the direct or indirect influence of motion. *

* I am duly sensible that I am at this spot bordering upon ground too soft to bear almost the lightest foot tread. Nor have I any wish here to enter upon a metaphysical controversy, as such is far removed from the objects of this paper. I have, however, been asked to define the pronoun we used in the above passages, a question which is an evidence of the great difficulty there is in throwing off that feeling of individuality which has so complicated the various systems of mental philosophy. It is, however, essential in a purely scientific inquiry to shake off the shackles of metaphysical mysticism, to free ourselves of the notion of an ego, and, regarding ourselves as we do the lower animals, we may make observations on our physical and psychical attributes.

It has been argued that if the mind be alone dependent upon changes in the material brain, that we can have no control over our thoughts and passions, and that we are, therefore, irresponsible beings, but this has been met by granting that we have the powers of volition. We avoid running into danger we are conscious of, *i.e.*, of which we have experience. Volition thus comes to be a dependent of experience, and results like it from the operation of impressions of things without. Again, that which we term conscience is but the standard of comparison of right and wrong, formed by experience in the mind of the individual. Almost the earliest impressions instilled into the infant by its fondling mother are coercive separations of right and wrong, as defined by her own conscience, separating in the infant mind on opposite sides of the standard line ideas of right and wrong often most puerile and not antithetical; as the child grows and the basis of his experience enlarges, his standard of comparison advances. Many of the puerile wrongs of infancy and childhood appear as wrong no longer, and his line of separation, *i.e.*, his conscience becomes fixed in accordance with the moral and civil laws of the polity in which he is placed.

The same phenomena obtain in all the other cells and collections of cells in the organism, and are not peculiar or limited to brain cells. We are not ordinarily conscious of having limbs till we injure them, or of having lungs or pleuræ, till they become inflamed, and after the first impression of the injury, or inflammation, we would perhaps be equally unconscious of the existence of these our belongings, could we keep them free from motion. But every movement of a broken leg acutely reminds us that we possess the member, and every respiration during a pleurisy, makes us consious that we have a pleura, or the increased vascularity of the inflammation maintains a motion which we become aware of as the phenomenon of pain. So in our brain, though we cannot perhaps say, without reservation, that a cell is injured because it is changed by the impression of an object, yet the change is itself sufficient to define and make evident that cell's existence among its fellows, whenever it or they together are subjected to the influence of motion.

We are conscious of an image so long, and only so long, as the cell or its atoms continue in motion, and our consciousness ceases when the cell again becomes quiescent; but disturb the cell's equilibrium again and the image is reproduced, however slight the motion. The cell becomes active whenever motion of another cell is communicated to it; the current or vibratile motion, inducing material change in the cell it reaches, very similar to that which took place in the one from which it proceeded, though in a less degree, while the appreciable phenomenon is the faculty of the mind we call memory. The memories, too, occur in order, and the order is more or less that in which we have gained our experience, *i.e.* received our impressions; for instance, if we can imagine a brain in which no impression has ever occurred, and place a rose before the organs of senses in connection with it, we shall probably first produce through the medium of sight the impression of colour; next through the intervention of the sense of touch, the impression of form, dimensions, &c.; and thirdly, through the olfactory nerves the impression of smell. Let the cells bearing these impressions become quiescent, then imagine a motion again reaching any one of them, its impression will be renewed, and that of the other two will again and speedily follow; thus it would appear that every idea we have in our memories has its location in a certain number of impressed cells close together. If now we allow, in our supposed brain, the impressions of the rose-tree to follow those

of the rose, the activity of the cells bearing the impressions of the rose will be followed by the activity of those bearing the impression of the tree ; and it is this process, occurring in our brain when healthy and, of course, stored with its multifarious impressions, that gives us the phenomenon of mind which we call relative suggestion. Complex as are the ideas in all ordinary minds, their reproduction is always more or less in order; and although the greater the number of impressions that our brains bear the greater and more multifarious will be the ideas we remember, yet on analysis of our thoughts we shall find that they always follow some order, and we may trace back each idea to some other intimately related to it; thus, in the healthy brain, thought occurs in a sequence of ideas, each idea being suggested by, and more or less relative to, the one preceding it, or at all events related to it by association or by the order in which its impressions were first received. We see a lamp—we have the idea of light; light suggests the sun, the sun the sky, the sky astronomy. In this we see in its most simple form the manner in which in the complex workings of our daily thoughts the multitudes of impressions that pass in review are called up; motion from one active cell being communicated to others in natural order, as motion is communicated from atom to atom of metal when a current of electricity passes through a wire.

The second phenomenon of mind or judgment I will here merely touch upon in its physical aspect, being desirous to leave all metaphysical considerations out of the paper as far as possible. A new impression in a cell is immediately brought into relation with the memories, motion being necessarily communicated from a newly impressed cell to others located in or near the same spot: this allows that comparison of impression with impression by which the new one is corrected, the process by which in the lowest degree simple ideas are formed, and by which in the highest degree we have that affirmation or negation of idea about idea which constitutes the function of mind called judgment.

The same process occurring in many cells, and taking place in a brain stored with many impressions and ideas, whereby the phenomenon of sequence is sufficiently perfect to permit two or more in juxtaposition to be prominent, allows that inference of one judgment from several which constitutes that faculty of the mind which we call, in its logical term, reasoning.

I would here cite music as a very remarkable instance, and

perhaps the most simple illustration of the identification of mental phenomena with the physical effects of motion. It is incontrovertible that music is a modification of motion, which reaches the aural organ of sense in waves, varying in rapidity, called sound. The reception of the impression by the brain is one factor of the vital phenomenon—the resultant of the motion of those waves of sound which reach certain cells from the aural sense organ, and the potential energy of those cells.

The cerebral cells which bear the impressions of the vibrations that produce sound are arranged in such exquisite relationship to one another that musical notes take their place in *ordo naturalis*, and in the simplest idea the notes of an octave can only follow one another in a sequence ; and the fact that the reproduction of the impression of one note will immediately be followed by the remembrance in natural order of all the remaining notes either higher or lower in the scale of that key, directly points to the conclusion that the same influence which aroused the activity of the cell bearing the first impression has passed on to those cells bearing the impressions which appeared secondarily ; and if we admit the influence of the first impression to have been motion, the conclusion is inevitable that that of the second is motion also, and that a proportion of that motion which aroused the first impression passed onward to the cell bearing the second.

We may pursue these phenomena further by considering the relation which certain members of the order of musical sounds bear to one another. If we take the common scale of C, or the natural key, the sounds that we call C D E F G A B follow one another in a sequence; but though this is the most simple, yet it is not the only sequence, for certain of the cells bearing these impressions appear to have secondary relationships—thus the 3rd, the 5th, and the 8th or 1st notes of the scale bear so close a relationship that if the 3rd be struck the others will follow in the mind as conclusions of an *a priori* character; or if all the three notes are struck together they agree, or judgment affirms their relation, and we are conscious of harmony, or, if struck in a sequence, we are conscious of their natural and harmonious association. Again, if we sound the 4th, the 5th, and the 7th, we are again conscious of something like harmony; yet not perfect harmony, for the mind is not satisfied; and although we have what musicians call an essential discord—although judgment affirms somewhat, yet the affirmation is incomplete—the

essential discord stands as it were a low barrier midway between two ideas, for judgment is satisfied the moment the relative harmony—composed of the 1st, 3rd, and 5th, or the 3rd, 5th, and 8th—is again struck. So absolutely irresistible is the return to the harmony after the essential discord that it may almost be regarded as a necessity; in fact, in some highly trained musical minds so absolutely a necessity is it that after the striking of any essential discord a painful impression remains until the discord has been resolved. It would be not unreasonable to assume that the motion affecting the cells in the production of the first impression of harmonious sounds when diverted from its natural channel, so disturbs the normal quietude of other cells that the painful impression occurs from their incongruous agitation, which remains until either the motion inciting them is expended, or is again turned into its natural channel. Before the final harmony is struck, any variety of concatenation of musical notes may be introduced, in the same way as a sentence may have any number of parentheses, so long as it has its logical conclusion or sequence. It is upon this that the beauty of music depends; but whatever the number of interpolations of concatenations, and however harmonious these may be, it is none the less necessary for the final harmony to be struck before judgment is satisfied. The affirmation of idea about idea is thus the harmony of impressed cells, a current of motion reaching a cell, bringing all its relations into activity with it in their natural order, and without producing any painful or inharmonious vibrations.

I would next illustrate the idea by consideration of one of the other senses, and I think we can have few stronger evidences than those, both positive and negative, of change in the material brain, associated with the impression and retention of words. I have not any intention of here entering upon the subject of Aphasia beyond the evidence afforded by it that language, or the impression of words, has its localization in some particular spot in the brain, which spot we may call the language, or the *word-holding*, organ.

It is certain that every word that has a place in that organ must have made some alteration in a cell before its identity could have become indelibly traced in that cell, or before its entity could have become a part of the entity of the particular cell that bears it, and it is equally certain that the alteration is induced through the agency of motion. We gain our experience of words—firstly, through the medium of

sound; secondly, through the medium of that mode of motion we call light. The impression of words from sound is exactly similar to that which we have seen in the case of music; certain waves of vibrating atoms impinge on the organ of hearing, and thus set up a motion which is conveyed to the cells which are the centres for the reception of verbal speech.

The inception of words through the agency of light is almost precisely similar, varying only in the mode in which the motion originated. We see a written or printed word because certain waves or rays of light so impinge on our retina as to reproduce in it the form of the written or printed sign; these rays of light are incontrovertibly motion, and the motion thus communicated to the retina is conveyed through the nerves to the recipient organ of verbal impressions, then meeting with the potential energy of the cells inducing the chemical and impressive change and also the third change, as we have already seen. So long as the seat of verbal impressions remains healthy, the various motions of the mind will call into prominence whatever word is wanted to express an idea, provided the *word-holding* organ possesses such a word, or provided that some cell bears the impression of the word associated with the idea; for instance, we see a rose, we have a mental impression of the flower, and we instantly give it its name; perhaps from habit—at all events from education—we always associate names with persons and things, and words with ideas. So that when we look at a flower we have seen before, the cells bearing the impression, instantly communicating with the word-holding organ and exciting it, we remember at once the name; and this, like the sequence in musical notes, always occurs in natural order. If, however, we look at a flower we have never seen or heard of before, or of the class and order of which we know nothing, we cannot associate a name with it, because in the word-holding organ there is no word related to the mental impression of the flower, and therefore none to be called into remembrance by it; the motion, communicated to the brain by the sight of the flower, merely induces the impression of form, size, colour, quality, &c., and any attempt to associate it with a name with which we are familiar will be negatived by the reproduction of a mental impression of the flower associated with that name.

The same phenomena are to be traced in consideration of all the sense organs. The sense of touch also as certainly gives us various impressions of the relation of bodies to space;

affecting cells which in their natural order are aroused by the activity of the cells bearing the other sense impressions of the body, in contemplation the revival of all the elementary impressions, formed through the medium of the various senses, and giving that complete idea, which for the want of one of the simple impressions might be warped, narrowed, contracted, or exaggerated. So certainly are the impressions ascribed to touch the results of motion, that this sense requires no further demonstration.

The evidence afforded by diseased conditions is very characteristic, especially where comparison can be drawn between the mental phenomena during life and the condition of the brain after the death of the individual. If our proposition be true in every case in which the maintenance and nutrition of the surface cells* is perfect, we ought to have retardation, imperfection, or arrest of the normal phenomena, varying, of course, in every shadow of degree with the loss of conductive power or the degree of tissue change in the brain itself.

If we measure the rapidity with which an electrical current will pass through a certain length of copper wire, then cut out a portion of that wire and introduce in the gap an equal length of platinum, an alteration in the rapidity of the current will be discovered, and if we substitute glass instead of platinum, the current will be found to be altogether arrested. So also in the brain substance; any alteration in the normal constitution of the cells or fibres will retard or arrest the motion communicated from externals,† while the greater or less degree of absence of potential energy in the cells themselves is fatal to the production of perfect impressions. We have, in consequence, but fleeting and imperfect images, loss of memory, sometimes apparently inordinate impressions, loss of attention, and incoherence. In

* There is ample reason to believe that the seat of intellectual impressions is the surface of the brain, since its internal parts are ganglia presiding over special and definite functions. It is almost unnecessary to state that these cells vary in their form and in the number of fibres they give off, that they are connected together by fibres, and also that certain of the fibres which they give off form the white matter or material of connection between surface and ganglia.

† This idea has been objected to on the ground that electricity passes with equal rapidity through all kinds of brain matter, whether diseased or not. It must, however, at once be seen that such objection is untenable and illogical. Vitality is not electricity, and an atrophic or fatty cell certainly has not the same amount of potential energy as one that is healthy and intact.

almost all such cases, especially those in which loss of the faculty of attention is a marked characteristic, the prominent physical condition of the brain is that of atony; and the fact of the loss of potential energy depending upon this change is an almost daily observation, not as regards the brain only, but as it affects every tissue of the body. Still more evident is the loss of potential energy in atrophic or wasted cells, or in amyloid cells and fatty cells in which the atomic elements are either not replaced or else amyloid particles or fat globules are substituted.

Some very strong evidence may be obtained from an analysis of incoherence of thought as manifested by incoherence of speech. In the delirium of fever, the confusion of some of the commoner forms of insanity, and the meaningless chatter of delirium tremens, a patient will often constantly repeat two, three, or more sentences which have not the least apparent connection; other patients of the same class may be observed to commence a sentence, expressing some of the simpler ideas in their natural and logical sequence, and then suddenly to lose the thread and continue or finish his sentence upon an entirely different subject; sometimes the thread of the idea will be lost twice, or three, or more times, the utterance being disjointed, part sentences, without regard to beginning or ending—or should he be capable of writing, his productions will be a string of incongruous, extravagant phantasms, or wild, unconnected, and fractional imaginings; but a closer study of such cases will show that the most incongruous and unconnected of these ideas are not altogether free from connection, and although often very widely disjointed, a slight web of connection may be traced through the whole of any particular set of wanderings, and it would appear as though, in the case of the unfinished sentence, the current which aroused some few ideas in natural sequence had suddenly ceased; or in the case of disjointed sentences, after waking into quasi activity a few cells in natural order and relation, reaching others more healthy, *i.e.*, with more potential energy than those immediately before excited, it had darted off, at a tangent, as it were, in the direction of the greatest vitality, waking impressions in natural sequence only so long as the cells bearing sequential ideas were more perfect in their physical constitution than others in proximity. There will generally be found some slight connection between the antecedent impression and the new idea, for the current can only run from one cell to another in con-

nection with it, although the extremes of the divergence of ideas following the relation of suggestion in two directions, but starting from one simple impression, may be so wide as to appear altogether without relation. It is perhaps owing to the facts, firstly, of each individual gaining his impressions in a different order to another, and secondly of the variation in individuals of the number of new impressions which may at different times be communicated from any one external object, that we obtain so great a variety in the sequential impressions and ideas of individuals, and so endless and so infinite a variety in the ideas one object may create in the human mind. A current of thought starting from an impression newly made or reproduced in any cell runs in one or more definite courses, but not necessarily always in precisely the same; were this the case, thought would be finite, narrow, and contracted, and confined to repetition; traversing and re-traversing a beaten track, as is the case with some lowly organised minds. We cannot interrupt the sequence any more than we can intercept the current of electricity in a wire, except by directing the current into another channel; that is, we cannot prevent the reproduction of impressions when a current has once started, except by placing another object more prominently before us, and thus directing the motion into another channel; but we have the power of continuing the current of thought in any channel or in any number of channels that may proceed from any given impressed cell for any length of time; the only limit to the ideas which may be suggested by any one given object or idea being the limit of our experience, or the paucity of cells bearing impressions relative to that particular object or idea. It is from this cause that thought can only follow the law of relative suggestion, for, unless we except transmitted memories or impressions, we have no innate ideas. Creation of ideas, except from the balancing of impressions already fixed in our brain cells, is as impossible as creation of matter. We are enabled to place new objects before our minds, either through the medium of our senses, or our recollection, whenever we will to do so, and as the motion set up in the reception or remembrance of an impression passes from cell to cell, it wakes, as it were, and makes prominent in these, the impressions which they bear; impressions perpaps long dormant, but now called forth for comparison, or judgment, or reflection, or to serve some office in the train of thought.

In the healthy brain activity can be maintained very well,

and, as it were, restricted for a time among certain sets of cells, the potentiality of the restriction constituting the faculty of attention, and the more perfect the quality of the cerebral substance, the greater is the possibility of developing this faculty. We can listen attentively to one person, and keep the current of thought intently fixed upon the subject of the speaker till he ceases, or until we are interrupted by a second person, in which case we can afterwards return to the first and reproduce the impression formed by his subject as though we had had no interruption. In a perfectly healthy brain, also, we can maintain and hold the impression of a given object the most prominent of all impressions till the cell or cells bearing it are tired or exhausted, or till the material atoms of the cell are so far changed that no further motions can occur till the cell is renovated. Hence we see the necessity for rest as well as nutrition, in the healthy action of the brain, the rapidity of nutrition not being able to keep pace with the exhaustion consequent upon attention. We are able to place a new object before our minds whenever we will and concentrate our attention upon it, and as we have not two attentions, and can only reason about one object at the same absolute moment—for when we seem to think about many things at once, we do not actually, but merely allow various objects to pass before us in rapid succession—it follows that the power of our mind will be the greater the more perfect our faculty of attention, while the loss of this faculty, or of the power of exercising it, constitutes the ruling abnormality in a large section of those individuals we call insane, in whom it is exhibited in the several forms of incoherence. In the abnormal brain, no permanent impression can be made, as little or no change is possible, a current cannot be maintained among any one set of cells, no perfect idea is formed, and the thought is lost—lost because the current which started it has reached a cell almost inert, or else, having been diverted into another channel, it has produced an abortive idea and abortive sequence, as fleeting and imperfect as the one before it. This phenomenon is strangely analagous to the phenomenon of dreaming—a state in which the faculties are almost all in abeyance, but in which some wakeful cells revive their impressions, while currents maintain errant courses without restraint or control, and wander far and wide over the broad and open area of that cellular structure which bears these wonderful, vivid, but as yet inscrutable impressions.

The close and parallel conditions of dreaming and incoherence is no new idea, but was recognised long since—by poets, however, rather than physicians. Tennyson beautifully illustrates this in his *In Memoriam*, as "the kinsman of sleep and madness." McNish, in his "Philosophy of Sleep," advances this idea, which has become very generally recognised by psychologists.

But again, accepting our proposition of motion, we find negative evidences of its truth in loss of memory, a condition in which no permanent impression communicated through a sentient nerve makes a lasting impression upon a cell. The individual in such a case will see, but not observe, and the passing objects of the present will find no place in his mind. Attention, if possible at all, will be a great effort, and even if the effort be made, will be followed by a speedy forgetfulness of all the attendant circumstances. Such cases are common enough, and exactly illustrated by general paralytics and demented subjects, in whom the only condition of brain cell we, as a rule, find after death, is atony or atrophy. In such cases, during life, the mind often becomes a perfect and complete blank. But since we do find the condition so constantly, and since we admit from actual experiment that in health the brain cells receive communications from externals through the agency of motion passing as currents through the sentient nerves, it follows that in these cases the cells themselves must be incapable of undergoing that change which is necessary for the production of impressions, therefore that their vitality, or potential energy, is diminished, and therefore, also, that they are incapable of communicating the motive currents further, or much further, to the cells in immediate proximity. The same conclusion is to be drawn when inordinate impressions are formed, giving the idea of hypercharactration. Such hypercharactration, however, often appearing as inordinate attention, is only apparent and is not voluntary, and results from the atonic cell retaining a sufficient amount of its normal element to admit of a primary impression being formed, but not sufficient to allow the current to pass on and arouse secondary and corrective ideas. Hence we have a strong impression, but no judgment. A few cases illustrative of this would help to elucidate my point, but as my space is limited I must desist, though I feel convinced that the more we examine clinical cases and accurately analyze both the single, prominent, and strong impressions, and the incoherent gibberish of unsound minds,

we shall not only learn much of movements of the mind, but in the beautiful and delicate structure of the human brain discover much to elucidate the objective and subjective phenomena of vitality, and the more confirmatory still will be the evidences that we are dealing with a mode of motion. So strangely in relief, however, do the single delusions sometimes stand out, on account of the inactivity of perhaps almost all portions of the brain, except that associated with the one idea, that it is not perhaps surprising that the idea of monomania should have at some time crept into psychological medicine. A little careful examination and study will, however, often indicate the exciting cause of such delusions, all of which have their origin out of, and not within, the brain. I could detail several cases of singular interest, had I space. I will merely mention one in which the patient believed that he had no bowels; the delusion was easily traceable to ten days torpidity of those organs, which, when relieved, was followed by a delusion that he had neither bowels nor sphincters, because for a day or two after successful evacuation he was unable to control his dejections. The evidences in this case were those of mal-nutrition. The patient perfectly recovered. Among other cases I might mention from my own observation, are several in which patients have believed that they had small animals in their insides, as instanced in one in which the delusion was that of a little dog in the stomach (abdomen). These cases I have generally found to be in female subjects; all of them cases of mal-nutrition, and the exciting cause of the delusion ovarian irritation.

The phenomenon of morbid speech again affords a strong confirmation of the truth of the theory of motion in its relation to mental activity. Misplacement of words, such as we sometimes notice when a person is impelled to use expressions conveying exactly the opposite meaning to that which he desires, as for instance characterising a fine day as a wet one, and *vice versâ*, miscalling names, as instanced in addressing the male members of a family by the names of the female, and *vice versâ;* or again, those curious cases as illustrated by that authentically related of a lady who, in repeating the Lord's Prayer, was impelled irresistibly to say, "Our Father, which art in Hell;"—seem as strongly significant of imperfect conduction and imperfect motion among the atoms of the nervous fibres and vesicles, as it is significant of a partial loss

of vitality of those particular structures, which no one probably will feel inclined to question.

There are on record several remarkable instances in which the phenomenon of morbid and perverted speech has been followed by cerebral hæmorrhage, right-sided hemiplegia at length explaining the anomaly, as it probably may in many similar cases, confirming a suspicion of a slow and progressive change in the vessels, accompanied by a slow and equally certain change of the cells in that immediate part of the brain. An arrest of their nutrition, a diminution of their potential energy renders them incapable of that perfection of activity necessary to revive or reproduce the spectrum of the word that an idea, or person, or body should have called forth or suggested.

The same phenomenon is not unfrequently the precursor of an epileptic seizure, the impoverishment of the brain tissue and the imperfection of the vitality of the cell in this appalling malady being incontestable. In these cases, various forms of illusion and subjective phenomena, as the ideas of soft breezes, or small animals running up the arms or legs or back till they reach the head, or perversion of vision, or smell, or taste, are all confirmatory of the diminution of vitality of the brain, and the impossibility, while the brain is passing into that anæmic condition, which is the proximate cause of the epileptic manifestation, of motion passing onward from the impressed cell to others, the revival of the impressions in which might, to use the metaphysical expression, correct the impression of the one that is active.

It will now be my endeavour to consider whether any practicable application of this theory may not throw some light upon that class of disease which we term subjective, all forms of which, I believe, can be traced to an arrest or absence of that motion which we term potential energy or vitality.

In dealing with disease, the error into which physicians for a long time fell was the one that now constitutes the popular notion, viz., that disease has an existence *per se*, that it is an entity separate and distinct from the individual it affects. It is of high importance, therefore, that in the investigation of the nature of disorder we should clearly conceive that we are dealing with a condition. The popular notion is that disease has an existence *sui generis*, and stands in the same relation to the individual as the medicine given to cure it. Disease, however, has no existence other than the modification of the organ or organs it is attendant upon.

This is, perhaps, especially true in regard to pain, spasm, convulsion, epilepsy, and nervous disorders generally. We are in the habit of classifying symptoms as subjective, when we cannot discover any material change in structure, and objective, when we can discover such tissue alteration; but it is nevertheless certain that whatever be the symptoms and however inscrutable and fleeting the tissue changes may be, there must be changes, otherwise we should be arguing for effects without adequate cause.

Observers long ago determined that the class of diseases characterised by pain, spasm, and convulsion, were due to over action, and it is strange how pertinaciously the opinion was long adhered to.

When the writhing agony of tic, the violent spasm of tetanus, or the hæmorrhagic congestion of the second state of epilepsy are witnessed it is not perhaps to be wondered that the *prima facie* inference should have been undue excitement and over action; but it is evident that such an idea would never have been formed had all the phenomena been carefully noted, and the evidence afforded by each carefully weighed.

Again, in what is termed nervous excitement, as instanced in the delirium of fever, the restlessness of delirium tremens, and the apparent over-action in several forms of insanity, particularly in paroxysms of mania and the excited stages of general paralysis, the ultimate exhaustion renders it evident that the over-action was not real, but due to the arrest of the activity, or the diminution of the vitality of those cells wherein the function of control is vested, thus allowing the potential energy of others to expend itself rapidly till they reach the state of stasis, or are exhausted; being analogous to a watch, in which we have removed the hair spring, when the machinery rapidly performs its revolutions until the potential energy of the main spring is exhausted, and then it stops.

It may be laid down as a rule that the amount of action the muscular system is capable of performing, and the amount of control which the central nervous system is capable of exercising, are in the healthy animal accurately and perfectly balanced, while any undue excitement visible to us in the former is to be received as evidence of a diminution of power or loss of vitality in the latter.

In endeavouring to find an adequate cause for perverted nervous function, and after a careful examination of a large num-

ber of cases and the lesions associated with them, I became the more convinced that in nervous disorders, especially those characterised by pain, spasm, and convulsion, we are dealing with a definable, physical condition. I have no objection to the use of the term subjective, as far as the actual manifestations or resultants are concerned; but we must go further and consider the objective, and I feel some certainty that we shall discover that objective in a change of the material of the cells of the brain, whereby their potential energy is so diminished that perfect vital phenomena cannot occur.

In those disorders in which paralysis is the prominent characteristic, the arrest of motion is so evident as to require no further demonstration, and in such cases, after death, we usually find sufficient tissue change in the brain to account for the arrest of function during life.

In those disorders, however, in which convulsion and spasm form the prominent characteristic, the arrest of motion is not always evident, and a closer scrutiny is required in order to render it so. In the passive form, and in the first stage of epilepsy, the almost suspended animation would point to a general arrest or diminution of potential energy, but the second stage would seem to point to the opposite conclusion, and therefore it is necessary to investigate all the conditions more closely.

After searching closely the records of inspection, during ten years at Guy's Hospital, with a view to discover a cause, and to fix the seat of lesion attendant upon convulsive disease in some definite spot, I was forced to the conclusion that there was no definite spot to which the attendant lesion of epilepsy might be referred, and though serious lesions are, in a great many cases, to be found on the surface of the brain, yet, often, no lesion that is at once demonstrable is discoverable at all, and when lesions which could not fail to attract the eye have occurred, they have so varied in their position, that, although they might have been an indirect cause, they were not the proximate cause—the *fons et origo morbi;* and while we regard morbid appearances after death, and endeavour to associate them with the morbid phenomena during life, we must not forget that many of the pathological changes which we see are often secondary, and the result, rather than the cause, of the affection. Instances of chronic Mania, Idiopathic Epilepsy, and progressive Locomotor Ataxy constantly furnish evidence on this point.

The mass of material that I have collected in regard

to epilepsy, however, furnishes very conclusive evidence upon two points ;—1st, that the primary seat of lesion is the surface; 2ndly, that the immediate exciting cause of the attack is anæmia of the surface. I have endeavoured to show that in health there is a perfect relation or balance between the control residing in certain cells of the brain and the contractile power vested in, and the attribute of, the muscular system, also that the seat of control, as also necessarily of volition, is the surface. If, therefore, any motions occur in those certain surface cells which have relation to volition, activity in the cells of the motive ganglia with which they are connected follows, whereby a disturbance of equilibrium is induced, and a condition analagous to electrical discharge ensues. The disturbance of the equilibrium of the motive ganglia arrests the control which these so called motive ganglia have over the muscles, with which, through the nerves, they are connected ; a current then passes through the nerve from the muscle, resulting in a contraction of the latter. Muscular contraction being the temporary removal of that control whereby the muscle is retained in a condition of static tension or equilibrium.

It is perhaps as well here to notice the fact discovered by Galvani, and afterwards established beyond doubt by Nobili, of currents passing along nerves in the direction from the periphery to the centre. It was, however, long the notion that currents passed in two directions—viz., from the periphery to the centre conveying to it impressions, and from the centre to the periphery conveying mandates or stimuli to the muscles, which then contracted from an inherent property of contractility.

The experiments of M. Matteuci, in 1842, and those of Professor Du Bois-Reymond, have however, proved beyond all question that in the contraction of a muscle the current passes not from the centre to the muscle, but from the muscle in the direction of the centre.

The experiments of Du Bois-Reymond and those of Dr. Radcliffe show that during inaction the natural state of living muscle is one in which the longitudinal and transverse surfaces of the fibres are in a state of (electrical?) antagonism, the longitudinal surfaces being positively and the transverse negatively electric, while the state of action or contraction is a condition of discharge.

As regards the nature of the currents they have been considered as electrical by the numerous experimenters who have specially studied them ; there is, however, no evidence to show

that the force inherent in the muscle is electrical, though no doubt electricity was what the experimenters dealt with, and measured with their galvanometers.

Their experiments, nevertheless, show that they were dealing with a mode of motion, and this mode of motion which is inherent in the living muscle and manifests itself as life, was converted into or manifested as electricity in their experiments, and at the time that they measured it by the galvanometer.

If the vitality of the surface cells is diminished, their controlling influence is diminshed also in a corresponding degree. Contraction may then occur in the muscles, and continue till the amount of muscular exhaustion balances the amount of potential energy wanting in the cells, when equilibrium is restored, though often the subject is left feeble and requires rest and sleep for the renewal of potential energy.

In the set of cases associated, for instance, with tumours and pressure, certain surface cells are completely destroyed, while those immediately surrounding are, some in an atrophic, and others in an atonic condition, and though there may be sufficient potential energy in the remaining cells to exercise perfect control under equable and passive conditions of the organism, a very slight amount of activity or excitation, induced either by external impressions or mental exertion, will so diminish their control over the muscular system that muscular discharge will of necessity follow, and in degree varying in proportion to the amount of brain surface affected and the amount of control deficent.

It is, however, certain that epilepsy occurs in two distinct forms—*Le grand mal*, and *le petit mal*—the variation resulting accordingly as the motive ganglia or the general surface of the brain are more affected.

In *le grand mal* any excitation of the motive ganglia under certain conditions of exhaustion instantly induces that anæmia of the brain which is the immediate cause of the loss of consciousness, and for a longer or shorter time the whole organism remains in a condition of tonic spasm. As the blood again begins to circulate through the brain, the tonic spasm passes off, because general control is more or less restored, and sometimes partial consciousness with it; but special control, that which possibly should be seated in a particular spot which is disorganised, being incapable of restoration, or incapable of speedy restoration, a series of muscular discharges, or that which we know as clonic spasms occur, until the potential energy of muscular and nervous systems respectively balance one another.

In *le petit mal*, the primary seat of affection appears to be the general surface, while the motive ganglia are but little affected; the anæmia of the brain, induced by any excitation, may be followed by slight spasm, and the muscular control may be almost immediately restored, while the mental faculties may remain for a long time altogether in abeyance, or they may be partially restored, under which condition we may witness the most strange and extraordinary instances of mental perversion which ever pass under the observation of the physician.

By entering fully upon the subject of epilepsy generally, and especially in regard to *le petit mal*, I could bring forward a mass of most interesting facts, all of which would support and illustrate the proposition of motion I have enunciated in regard to vital, mental, and cerebral phenomena: the subject of negation and perversion of mind attendant upon *le petit mal* is, however, so large that it is more fitted for a separate paper, and one which I hope to be able before long to bring forward. The conclusion, nevertheless, to which pathological observation points is the same as that indicated by clinical observation—viz., that *le haut mal* or *le petit mal* are phenomena which are produced according as the centres of intelligence or the centres of muscular control are primarily the seat of lesion or affection. The loss of consciousness is usually the subjective phenomenon first appreciable to the observer, but its occurrence is secondary altogether, and the result of the anæmia of the brain, which again is secondary to and the result of contraction of the capillaries of the brain, which contraction is itself the result of irritation, caused by exhaustion; the brain cells themselves wanting potential energy to enable them to antagonise the currents produced by external objects or the ordinary motions of the mind.

It would almost appear as a conservative effort, that the capillaries contract because the cerebral cells are exhausted and irritated; loss of consciousness follows from the absence of so much blood in the brain as is necessary for the maintenance of the motion of thought, and the chemical phenomena associated with it; next, control being removed, the potential energy of the muscular system is able to expend itself; and lastly the relation between the control of the centre and the potential energy of the muscular system becoming equalised, the exhausted subject is enabled to rest, and therein to recover potential energy in both nervous and muscular systems.