"In the evolution of such an establishment, the many difficulties that must have stood in the way of such an undertaking, due credit must be given to those gentlemen who formulated the theory and put in practical operation the present system of disinfection.

"From the series of observations made in determining the temperature of the chamber for the application of dry and moist heat, it is clearly shown that the time prescribed is entirely too short when the chamber is filled with goods; more especially is this noticed when the chamber is filled with such goods as blankets, mattresses, and cushions. Unless a longer period of time is given to each charge, it is certain that only a partial disinfection is accomplished.

"It was suggested to Drs. Wilkinson and Aby that the defects of the present style of steaming-apparatus could be best overcome by adopting the application of dry and moist heat under a pressure of from ten to twenty pounds. To accomplish this it would be necessary to have new machinery, — instead of the steaming-chamber now in use, to have constructed a large chamber of boiler-iron, capable of standing at least twenty-five pounds pressure to the square inch, and provided with one bulk-head door that could be properly secured to make it steam-tight, being provided with suitable appliances for ascertaining the temperature in any part of the chamber. In this manner the disinfection by steam and dry heat could be thoroughly accomplished, and much more speedily than at present. Lighter articles, such as clothing, etc., when not too much crowded, received sufficient heat to disinfect them.

"We are informed by the president of the board, Dr. Wilkinson, that the matter was laid before the health board, and it was by resolution decided to remove the present location of the quarantine station to a place farther down the river, in order that there could be complete isolation; and, guided by the result of the experiments undertaken, a heating-chamber capable of sustaining sufficient pressure from within will be erected, thus insuring an equal distribution of heat and the possibility of attaining and maintaining a much higher temperature than at present; also that an order would be given to the resident physician to the effect that the steaming-chamber should not be so heavily charged, and the time of exposure be extended to a sufficient limit to insure a proper degree of heat.

"It is believed that if, before the application of sulphur dioxide to the holds and cargoes of vessels, the holds be thoroughly aerated by means of the exhaust-fan and the use of a greater quantity of sulphur, confining the gas in the vessel, say, a period of not less than thirty-six hours, then the application of the bichloride solution to the hold and between-decks will accomplish a thorough disinfection of the surfaces of vessel and cargo.

"It is shown that in the short process of fumigation prior to June 1 the gas does not penetrate to any depth in such cargoes as coffee, sugar, etc. After June 1, the time of detention being five days, there is insured a thorough application of the gas in its greatest germicidal power.

"The following conclusions may be drawn: —

"1st, That the application of bichloride solution to interior of the cabin, carpets, rugs, trunks, valises, rubber and leather goods, should be made in such manner as to insure the moistening of all surfaces.

"2d, The chamber should not be charged to more than half its capacity, and the time lengthened to at least one hour.

"3d, That the time imposed on vessels that have undergone the fumigating process prior to June 1 should be longer, and the application of bichloride to the interior of the hold should be done after the gas has been confined at least thirty-six hours.

"4th, That the establishment of the present style of apparatus is a great stride in the right direction, and has demonstrated its feasibility and the correctness of the principles involved.

"The president, Dr. C. J. Wilkinson, asserts, that, whatever degree of heat has been obtained, it is certain that no case of yellow-fever has developed on any vessel that has been subjected to this process; a fact, however, which was not uncommon under previous methods."

IT is announced that in October, 1889, the second triennial session of the International Congress of Hydrology and Climatology will be held in Paris.

PROTECTION OF BUILDINGS FROM LIGHTNING.

FROM the time that Franklin flew his kite at Philadelphia, and ascertained beyond cavil the true nature of lightning — from that time to the present, the protection of buildings and ships from its destructive agency has been mainly a matter of detail, and application of the laws of electricity so far as they were known.

For a long time the erection of lightning-conductors was opposed by the religious world as heretical and impious. But first in some Protestant provinces in Germany, and later in France and England, the use of the heretical rods gradually extended.

At some recent meetings of the London Society of Arts, Prof. Oliver J. Lodge has delivered a series of lectures on protection from lightning, in which he has summarized the prevailing opinions of scientific men.

The two main destructive aspects of a lightning-flash are (1) its disruptive, or expanding, or exploding violence; (2) its heat. The heating effect is more to be dreaded when the flash is slow and much resisted; the bursting effect, when conducted well, except at a few places. A noteworthy though obvious thing is, that the energy of the discharge must be got rid of somehow. The question is, how best to distribute it.

That conductors often fail is undeniable. It is customary to say they are not properly made, or that there was a faulty joint, or that there was a bad earth. A bad earth is the favorite excuse. A good earth is a good thing undoubtedly, and one cannot well have too much of it; but for a flash to leave a fine thick copper conductor on a tall chimney while still high up, and begin knocking holes in the brickwork in order to make use of the soot, or the smoke, or some bolts or other miserable conductors of that sort, because it is not satisfied with the moderate allowance of earth provided for it at the bottom, is evidence either of simple perverseness, or else of something more deep-seated and not yet properly called attention to.

If the earth is bad, the flash can show its displeasure when it gets there by tossing it about, and boring holes into it, and breaking water and gas mains; but at least it might leave the top and middle of the chimney alone, it might wait till it got to the badly conducting place before doing the damage. Yet it is notorious that on high chimneys a flash often refuses to follow a thoroughly good conductor more than a quarter or half way down, but takes every opportunity of jumping out of it and doing damage.

It may be said that the effect of the bad earth is to make the whole path so highly resisting that the discharge necessarily declines to take it. Well, if that were so, it need not have come into the conductor at all. It is supposed with one breath to strike the conductor, because it affords an easy path to earth; and with the next it is said to leave the conductor, because, after all, it finds it a bad one.

Besides, it need not be so very particular about a little resistance. It has already come through, say, half a mile of clear air: it might manage a few feet of dry soil. It strikes violently through the air, enters the conductor, and begins to go quietly. Why does it not continue to go quietly till it gets to the bottom of the good conductor, and then begin displaying its vigor by boring holes below, as it has done above? Why should one end have to be so persistently cockered up? Why not insist upon having not only a good 'earth,' but also a good 'sky'?

The old and amusing political controversy between knobs and points has disappeared. Points to the sky are recognized as correct; only Professor Lodge would advocate more of them, any number of them, rows of them, like barbed wire — not necessarily at all prominent — along ridges and eaves. For a point has not a very great discharging capacity. It takes several points to discharge readily all the electricity set in motion by a moderately sized Voss or Wimshurst machine: hence, if you want to neutralize a thunder-cloud, three points are not so effective as three thousand.

An earth is necessary, or you will have your foundations knocked about and your garden ploughed up. A good earth is desirable. A few tons of coke, with the conductor coiled up among it, is a well-known and satisfactory plan if the soil be permanently damp. A bag of salt might, perhaps, be buried with it to keep it damp throughout, or rain-water may be led there. Often, however, the most violent thunder-storms occur after a spell of fine weather, and the soil is likely to be dry. It is best, therefore, to run your conductor pretty deep, and there make earth.

It is all very well to connect the conductors to water-mains if near; but, if they are far off or non-existent, it is no use; and in no case, in Professor Lodge's opinion, should they be used as sole earths, certainly not gas-mains. In dry weather they are not earthed at all well, and a strong charge may then surge up and down them, and light somebody else's gas in the most surprising way. It does not often happen, but it may happen in sandy soil after dry weather.

It is a superstition to place much reliance on the testing of conductors with a galvanometer and Wheatstone bridge. A galvanometer and Wheatstone bridge are powerless to answer many important questions. A Leclanché cell can no more point out what path lightning will take, than a trickle down a hillside will fix you the path of an avalanche. The one is turned aside by every trivial obstacle, and really chooses the line of least resistance; the other crashes through all obstacles, and practically makes its own path. A flash strikes a house at one corner, rushes apparently part way down the conductor, then flashes off sideways to a roof-gutter, sends forks down all the spouts, and knocks a lot of bricks out. Another branch bangs through a wall in order to run aimlessly along some bell-wires, and then out through a window-frame, and down a spade or something propped up against the wall, to earth. The lightning-tester comes with his galvanometer and Leclanché cell, and reports that the earth of the conductor has one hundred ohms resistance; and the accident is therefore accounted for. But how much resistance would he have found in the paths which the lightning seemed to choose in preference to the one hundred ohms? Something more like a million probably.

Something has been left out of consideration, and something very important too; and until that something is fully taken into account, no satisfactory and really undeniable security can be guaranteed. That something is inertia, — electrical inertia.

The word 'inertia' one uses as conveying a correct general notion of the behavior of an electric circuit to sudden electro-motive forces, — a behavior which is caused by the influence or induction which every portion of a circuit exerts on every other portion. Consider a conducting-rod as analyzed into a bundle of parallel wires or filaments, and let a current be suddenly started in all. The rising current in any one filament exerts an opposing force on all the others; and this self-generated opposition electro-motive force, due to induction between the different filaments of the conductor, exactly imitates the effects of ordinary inertia as observed in massive bodies submitted to sudden mechanical forces.

The term commonly employed to denote the electrical inertia-like effect is 'self-induction,' which is becoming gradually shortened to 'inductance.' Its original form when first dealt with by Sir William Thomson was the 'electro-magnetic capacity' of the circuit.

Now, since electric inertia is due to a mutual action between the filaments into which a conductor may be supposed divided, it is manifest that the closer packed they are, the greater their inertia will be, and that to diminish inertia it is only necessary to separate the filaments and spread them out.

The main count of the indictment against ordinary procedure is, that too much attention has been hitherto paid to conducting-power, and too little to inertia. In fact, it is not too much to say that practically nothing but conductivity has been attended to, or thought of, in the erection of lightning-conductors.

Another way of putting the matter is this. A lightning discharge is essentially a varying current: it manifestly rises from zero to a maximum, and then dies away again, all in some extremely small fraction of a second, say, a hundred-thousandth or thereabouts. But that is not all: there is a certain amount of energy to be got rid of, to be dissipated; and it may easily be that a single rush of electricity in one direction does not suffice to dissipate all the stored-up energy of the charged cloud. If the conductor is highly resisting, a single rush is sufficient; but, if it be well-conducting, it is quite insufficient. What happens then? The same as would happen with compressed air or other fluid rushing out of an orifice. If it is a narrow jet, there is a one-directioned blast; but if a wide, free mouth be suddenly opened, the escaping air overshoots itself by reason of inertia, and springs back again, oscillating to and fro till the stored-up energy is dissipated. Just so is it with an electric discharge through good conductors: it is not a mere one-directioned rush; it is an oscillation, a surging of electricity to and fro, until all the energy is turned into heat.

There is another fact which it behooves us to be aware of. It is one to the importance of which the attention of scientific men has but recently been called. Experimentally it has been discovered by Professor Hughes; theoretically, by Mr. Oliver Heaviside, Lord Rayleigh, and Professor Poynting; for, though the necessary theory is really contained in Clerk Maxwell, it required digging out and displaying. This has now been abundantly done, but the knowledge has scarcely yet penetrated to practical men; indeed, it has not yet been thoroughly assimilated by most physicists. The fact is this. When a current starts in a conductor, it does not start equally all through its section: it begins on the outside, and then gradually though rapidly penetrates to the interior. A steady current flows uniformly through the whole section of a conductor: a variable current does not. It is started first at the surface, and it is stopped first at the surface.

Remembering the rapidly oscillating character of an electric discharge, remembering also the fact that a rising current begins on the outside surface of a conductor, we perceive, that, with a certain rate of alternation, no current will be able to penetrate below the most superficial layer or outer skin of the conductor at all. In the outer skin, of microscopic thickness, electricity will be oscillating to and fro; but the interior of the conductor will remain stolidly inert, and take no part in the action.

Thus we arrive at a curious kind of resistance, caused by inertia in a roundabout fashion, and yet a real resistance, a reduction in the conducting-substance of a rod, so that no portion except that close to the surface can take any part in the conduction of these rapidly alternating currents or discharges. It must naturally be better, therefore, not to make a lightning-conductor of solid rod, but to flatten it out into a thin sheet, or cut it into detached wires. Any plan for increasing surface and spreading it out laterally will be an improvement.

Perhaps it may be as well to guard against one favorite misconception. It has long been known that static charges exist only on the surface of conductors. It has also long been known that ordinary currents flow through the whole section and substance of their conductors. It is now beginning to be known that alternating currents may be sufficiently rapid to traverse only the outer layers of conductors; and this last piece of knowledge is felt to be rather disturbing by those who have been accustomed to dwell upon the behavior of steady currents, and seems like a return to electrostatic notions, and an attempt to lord it over currents by their help. But the first and third facts mentioned above — the behavior of static charges, and the behavior of alternating currents — are two distinct facts, independent of each other; not rigorously independent perhaps, but best considered so for ordinary purposes of explanation.

We have thus mentioned two causes of obstruction met with by rapidly oscillating currents trying to traverse a metal rod. First there is the direct inertia-like effect of self-induction to be added to the resistance proper; the resulting quantity being called by Mr. Heaviside 'impedance,' to distinguish it from resistance proper, for there is a very clear distinction between them. Resistance proper dissipates the energy of a current into heat, according to Joule's law; impedance obstructs the current, but does not dissipate energy. Impedance causes tendency to side-flash; resistance causes a conductor to heat, and perhaps to melt. The greater the resistance of a conductor, the more quickly will the energy of a discharge be dissipated, its oscillations being rapidly damped; the greater the impedance of a conductor, the less able is it to carry off a flash, and neighboring semi-conductors are accordingly exposed to the more danger. Resistance is analogous to friction in machinery; impedance is analogous to freely suspended massive obstruction, in addition to whatever friction there may be. To slowly changing forces, friction is practically the sole obstruction; to rapidly alternating forces, inertia may constitute by far the greater part of the total obstruction, so much the greater part that friction need hardly matter.

This is a fairly accurate popular statement of the direct way in which self-induction aids resistance proper in obstructing an alternating current. But, in addition to these considerations, there is that other indirect way which we have also mentioned; viz., the fact that conduction of alternating current may be confined to the surface of a rod or wire if the alternations are rapid enough. This cause must plainly increase total impedance; for the total channel open to such a current is virtually throttled, as a water-pipe would be throttled by a central solid core.

But which part of the total impedance does it affect? Does it increase the resistance part, or the inertia part? In other words, does this throttling of a conductor act by dissipation of energy, or by mere massive sluggishness? Plainly, it must act like any other reduction of section: it must increase the resistance, the dissipating-power of a conductor, the heating-power of a current. Hence the resistance of which we have spoken as entering into the total impedance has by no means the same value as it has for steady currents, and as measured by a Wheatstone bridge. It is a quantity greater — possibly much greater — than this; and, in order to calculate its value, we must know not only the sectional area and specific conductivity of the conductor, but also the shape of its section, and the rate of alternation of the current to be conveyed.

We may here note a vigorous controversy, or difference of opinion, between Faraday on the one hand, and Sir W. Snow Harris on the other. Faraday was often consulted about lightning-conductors for lighthouses, and consistently maintained that sectional area was the one thing necessary, weight per linear foot, and that shape was wholly indifferent. Harris, on the contrary, maintained that tube-conductors were just as good as solid rods, and that flattened ribbon was better still. Each is reported to have said that the other knew nothing at all about the matter. Of course, we know that Faraday was thinking of nothing but conduction, and conduction for steady currents. Harris had probably no theoretical reason to give, but was guided either by instinct or by the result of experience. In this particular, Faraday was wrong, and Harris was right.

But, it may be said, have not experiments often been made as to the advantage of tape over rod forms of lightning-conductor, with negative results? Yes, but the point usually attended to is the deflagration of the conductor. Mr. Preece, for instance, with Dr. De la Rue's battery, found ribbon and wire equally easy to deflagrate by the discharge. But we are not examining which form of conductor is least liable to be destroyed by a flash (probably there is not much to choose between one form of section and another, for there is no time for surface cooling): we are examining which form will carry off a charge most easily, and with least liability to side-flash; and here thin ribbon shows distinct advantage over round rod.

It is found that a rod of iron carries off a discharge more satisfactorily than a rod of copper. It would seem as if the poorer conducting qualities of iron enabled the discharge to penetrate deeper, and so to make use of a greater thickness of skin.

But, every one will say, surely iron has far more self-induction than copper. A current going through iron has to magnetize it in concentric cylinders, and this takes time. But experiment declares against this view for the case of Leyden-jar discharges. Iron is experimentally better than copper. It would seem, then, that the flash is too quick to magnetize the iron, or else the current confines itself so entirely to the outer skin that there is nothing to magnetize. A tubular current would magnetize nothing inside it. Somehow or other, the peculiar properties of iron, due to its great magnetic permeability, disappear.

If it turns out to be true that an iron rod does not get magnetized by the passage of a rapidly alternating current, it may be held a natural consequence of the fact that such currents flow mainly in its outer surface, and that such tubular currents have no magnetizing power on any thing inside them.

The magnetizability of iron is no objection to its employment in lightning-conductors. Its inferior conductivity is an advantage in rendering the flash slower, and therefore less explosive. Its high melting-point and cheapness are obvious advantages. It is almost as permanent as copper, at least when galvanized; and it is not likely to be stolen. Professor Lodge regards the use of copper for lightning-conductors as doomed.

It is found that a conductor is more efficient in carrying off a discharge and preventing side-flash, in proportion as its self-induction is lessened; say, by spreading it out into a thin sheet, or cutting it up into a number of wires, or otherwise. But no conductor is able to prevent side-flash altogether, unless it is zigzagged to and fro so as to have practically no self-induction: in that case the side-spark is nearly stopped. But so long as a conductor is straight (and a lightning-conductor must, of course, be straight), so long will there be some tendency to side-flash, however thick it be made. It may be a foot or a yard thick, and yet not stop it. A man touching a lightning-conductor, however well earthed, might perhaps receive a shock sufficient to kill him.

How can this tendency to side-flash be further diminished? To stop a pipe full of water from being burst by a blow given to the water, you will make the pipe elastic. An elastic cushion will ease off the violence of the shock of a water-ram.

Electric inertia was known by the other name of 'self-induction;' electric 'elasticity' is known by the other name of 'capacity.' Increase the capacity — not the thickness or conducting-power, but the electrostatic capacity — of your conductor, and it will be able to carry off more.

The only practicable plan is to expand it over as much surface as possible. A lead roof, for instance, affords an expansion of fair capacity which may be easily utilized; and there should be as little mere rod-projection as possible before some extent of surface begins. Flat sheet for chimneys is better than round rod: it has at least some more capacity, and much less self-induction.

For tall isolated chimneys Professor Lodge would suggest a collar of sheet metal round the top and at intervals all the way down; or a warp of several thin wires instead of a single rod, joined together round the chimney by an occasional woof; or any other plan for increasing capacity and area of surface as much as possible.

As to the liability of things to be struck, several questions suggest themselves: Is a small knob at a low elevation as liable to be struck as a large surface at a higher elevation? Is a badly conducting body as liable to be struck as a well-conducting one? In other popular words, does a good conductor 'attract lightning'?

In answering this question experimentally, one must draw a careful distinction between the case of a flash occurring from an already charged surface, which has strained the air close to bursting-point before any flash occurs, and the case of a flash produced by a rush of electricity into a previously uncharged conductor too hastily for it to prepare any carefully chosen path by induction. The two cases are (1) steady strain, (2) impulsive rush.

Experiment on the liability of things to be struck when the air above them is in a state of steady strain, gradually increased, shows that the flash actually prefers to jump three times as much air to a sharp point, and encounter a megohm resistance, rather than take the short direct path offered by a bigger knob.

By modifying the experiment so as to get an impulsive rush, all bodies are equally liable to be struck if at the same height, and no one is more liable than another: simply the highest is struck if they are at all equally conducting. But by making one bad-conducting, its protective virtue is gone. This is the real objection to a bad earth: it cannot protect well against these sudden rushes.

Sudden rushes are liable to occur: the clouds spark first into one another, and then, as a sort of secondary effort or back kick, into the earth. In these cases the best conducting and highest objects are struck, quite irrespective of any question of points and knobs. Points are no safeguard against these flashes. The point gets struck by a vivid flash. It has no time to give brushes or glows: its special efficacy in preventing discharge exists only in the case of steady action, where the path is pre-arranged by induction. In the case of these sudden rushes, the conditions determining the path of discharge are entirely different. No doubt they have to do with what is called the 'time-constant' of the various conductors.

Electrical oscillations are of considerable interest, and have sundry practical bearings. When a flash strikes a system, the electricity goes rushing and swinging about everywhere for no apparent reason, just as water might surge about in a bath or system of canals into which a mass of rock had just dropped, splashing and overflowing its banks. Just so with electricity. Bell-wires, gas-pipes, roof-gutters, conduct side-flashes in a way most puzzling to the older electricians; and thus gas may get ignited in the most unexpected places, and passengers in a train may feel a shock because a charge has struck the rails. In powder-magazines it is apparent how dangerous this lawless sparking tendency may be; for even the hinge of a door may furnish opportunity for some trivial spark sufficient to ignite powder. By no means should high rods be stuck up to invite a flash to such places. Build them, or line them, with connected iron, barb them all over the roof, connect them to the deep ground in many places, and but little more can be done.

These electrical oscillations and overflows, which it is easy to set up in a charged conductor, manifestly explain what is known as the 'return-stroke.' This fact — that a discharge from any one point of a conductor may cause such a disturbance and surging as to precipitate a much longer flash from a distant part of it — at once accounts for any 'return-stroke' that has ever been observed.

It is for this reason that it is possible that a tall chimney or other protuberance in one's neighborhood may be a source of mild danger; inasmuch as if it is struck it may be the means of splashing out some more discharges to other smaller prominences, which otherwise were beyond striking distance.

Finally, is it possible for the interior of a thoroughly enclosed metal room to be struck; or, rather, can a small fraction of a lightning-flash find its way into a perfectly enclosed metal cavity, for instance, a spark strong enough to ignite some gun-cotton in a metal-covered magazine which might happen to be struck?

The application of the laboratory experiments to powder-magazines is, that, if any conductor (like a gas-pipe) pass out of the building before being thoroughly connected with its walls, it is possible for a spark to pass from something in the interior of the building to this conductor whenever a flash strikes the building.

The complete and certain protection of buildings from lightning is by no means so easy a matter as the older electricians thought it. In many cases we may be content to fail of absolute security, and be satisfied with the probable safeguard of a common galvanized iron rod or rope. But for tall and important buildings, for isolated chimneys and steeples, and for powder-magazines, where the very best arrangement is desirable, what is one to recommend? Professor Lodge sees nothing better than a number of lengths of common telegraph-wire. He thinks a number of thin wires far preferable to a single thick one; and their capacity must be increased when possible by connecting up large metallic masses, such as lead roofs and the like. But the connection should be thorough, and made at many points, or sparks may result. Balconies, and other prominent and accessible places, should not be connected.

The earth should be deep enough to avoid damage to surface-soil, foundations, and gas and water mains. As to the roof, he would run barbed wire all round its eaves and ridges, so as to expose innumerable points, and the highest parts of the building must be specially protected; but he would run no rods up above the highest point of the building, so as to precipitate flashes which else might not occur, in search for a delusive area of protection which has no existence.

The conductors must not be so thin as to be melted or deflagrated by the flash; but melting is not a very likely occurrence, and, even if it does occur, the house is still protected. The discharge is over by the time the wire has deflagrated. The objection to melting is twofold: first, the red-hot globules of molten metal, which, after all, are not usually very dangerous out of doors; and, second, the trouble of replacing the wire. The few instances ordinarily quoted of damage to lightning-conductors by a flash do not turn out very impressive or alarming when analyzed.

MENTAL SCIENCE.

The Nature of Muscular Sensation.

THE active side of psychic life is represented by movements. The study of the ways and means by which these movements are brought about, are co-ordinated and directed to useful ends, forms one of the most important chapters of physiological psychology; but the elements that enter into conscious motion are so numerous, and so intricately connected, that our knowledge of the process is as yet very defective. It has been well said that the clear and definite statement of a problem is a long step towards its solution. While recent research has not succeeded in definitely explaining the nature of the sensations connected with movements, it has cleared the problem of many misconceptions which had attached to it, and called attention to those points from which a final solution may be expected. M. Binet has recently brought together the various aspects of the problem, and added thereto an ingenious suggestion towards their further elucidation (*Revue Philosophique*, May, 1888).

The first distinction that M. Binet emphasizes is that between the consciousness of a movement and that of the co-ordination of the muscles necessary to make it. The latter does not enter into the psychic aspect of movement at all. We may be, and usually are, unaware of the simultaneous and orderly contraction of the various muscles necessary to perform a useful act, and yet be perfectly able to do the act. It is the mental conception of the finished act that guides the muscles and gives unity to the movement. Our problem deals only with the methods by which we become aware that our muscles have obeyed the mandate of our will.

The simplest source of such knowledge is that obtained through the eye. We know that a movement has been accomplished, because we see it. Again, in speaking, we know that the muscular mechanism of articulation has acted properly, because we hear the resulting sound. The voices of speaking deaf persons are usually harsh, owing to the lack of the corrective power furnished by the ear. But, even with the eyes closed, we have quite a definite knowledge that the desired movements have been performed. The general sensibility, the feeling of effort as shown in the change of respiration, etc., the dermal sensations produced at joints, and the feeling of the shortening of muscles, — all contribute to the result. We are powerless to analyze the several *rôles* played by these factors by observing actions in ourselves; but here pathology helps us out of the difficulty, and shows what psychic factor is deranged when a physiological function is lost, as will be touched upon later. Again, this latter class of sensations can learn to control movements which at first require the aid of vision. Walking is a conspicuous example of such. All these factors have the one point in common, that they act after the muscles have contracted. They are due to impressions proceeding inwardly, centripetally, to the brain, and thus informing us what has been done.

The question has been raised, however, whether we have not knowledge of movement centrifugally before the action takes place; whether we have not an outgoing feeling of expended energy suited to the act in question. This view has been supported by many illustrious names, and it has been negatived with equally good authority. The objectors call attention to the fact that there is such a thing as a motor image formed from former sense-impressions, and that this is sufficient to call up the proper mental antecedent upon which the motion ensues. This tells us how much energy to discharge, leaving the rest of the factors to take effect when the action is done.

Pathology calls attention to cases in which the tactile sensibility is destroyed, hoping to draw important conclusions from the interference that this causes with voluntary movement. When such a patient performs a movement, he has only the visual sensory image to guide him; and, if this be taken away by blindfolding him, what will happen? This is the important test; but it is not unambiguous in its interpretation. Most patients will do an action at command with their eyes closed nearly or quite as well as with their eyes opened, the movements in question being those of an anæsthetic limb. They write with the feelingless hand as well as normally. From this observation we can at once conclude that the power of co-ordinating movements, and the consciousness of the motion, are two different things; for these same patients can have their limbs moved for them without their knowing it, thus showing that the centripetal part is interfered with. Another class of patients, however, are reduced, by closing their eyes, to a condition of almost complete motor impotence. In spite of persistent exhortations, they cannot take one hand in the other, touch their forehead, and so on. The upholders of one side of the question emphasize the former result, arguing that the centripetal sensations are not sufficient to direct motion (for here they are lacking), and thus show the necessity of assuming a consciousness of outgoing energy, an