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THE "MUSCULAR SENSE"; ITS NATURE AND CORTICAL LOCALISATION.[1]

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HAVING been honoured by a request from the Council of the Neurological Society to open a debate upon "The Muscular Sense; its Nature and Cortical Localisation," I willingly undertook this duty, not because I thought the task an easy one, but, recognising to the full all the inherent difficulties of the subject and the unsettled state of opinion thereon, I fully concurred in the notion that such a discussion might do much good. If it does not lead to the immediate settlement of the many points still in dispute, it may, at least, serve to bring out into clearer light the nature of the problems to be settled by future workers and thinkers, in order that unanimity may ultimately prevail. I say "thinkers" advisedly, because this is eminently one of those subjects on which observation and experiment alone will not suffice, especially observations and experiments conducted upon lower animals.

INTRODUCTION.

It may be regarded as a physiological axiom, that all purposive movements of animals are guided by sensations or by afferent impressions of some kind.

Physiologists know that the several kinds of movements

[1] Paper read before the Neurological Society of London, on December 16, 1886.

which animals are accustomed to perform are only artificially and for purposes of convenience divided into such classes as (1) reflex or automatic, (2) secondary-automatic, (3) instinctive, (4) ideo-motor, or (5) volitional.

From the point of view of the dependence of these several kinds of movement upon sensation, or upon afferent impressions either actual or revived, no fundamental distinction can be drawn between them.

In reply to this it might be alleged that volitional movements constitute a class apart, seeing that their performance implies as a necessary factor, which the others do not, the presence of, and illumination derived from, Consciousness. But it must be borne in mind, (*a*) that Consciousness is not itself a factor, it is rather of the nature of an epiphenomenon; (*b*) that it exists in varying degrees during the executions of different kinds of voluntary movements, being of maximum intensity during the performance of unfamiliar muscular actions and of minimum intensity (almost vanishing) in association with easy and familiar voluntary acts; and (*c*) that as a matter of fact, it is often almost impossible to draw anything like a dividing line between ideo-motor and voluntary movements, so insensible are the gradations between them.

If we compare for a moment a simple reflex movement with a volitional movement, some important differences may nevertheless be found, which are of great significance from the point of view of the subject with which we are now concerned.

A reflex movement may be evoked and guided to its completion by afferent impressions which are wholly unfelt; we have here apparently nothing else than a direct relation established between the paths of afferent impressions and the nervous cell and fibre tracts needful for evoking the suitable activity of some definite sets of muscles. In other words, the line of least resistance for the molecular movements set up in the cells on the afferent side is found to lie along the intermincial fibres connecting these with certain groups of motor cells, and thence outwards through their efferent nerve fibres to the muscles. Even in ideo-motor movements something of the same kind seems to occur; that is to say, there seems to be an equally well-formed beaten tract (by means of nerve fibres) between the cells of the perceptive centres in which

the idea or revived sensory process occurs, and the particular motor mechanisms connected therewith, whose excitation gives rise to the fitting movement.

But simple, familiar, voluntary movements are attended by so little conscious illumination as to be often indistinguishable in every way from ideo-motor movements. The utterance of words in ordinary speech, that is, in the person's own language, is effected by movements which may be described either as voluntary or as ideo-motor. The whole act of speech is truly a voluntary performance; but the enunciation of each word takes place with all the ease and lack of attention typical of an ideo-motor movement. It is, however, in the performance of a new or unfamiliar voluntary action that we find the widest divergence from the phenomena attendant upon the execution of a simple reflex movement. Here we have the full blaze of consciousness, the whole attention of the performer, directed to the production of the movement in the desired manner, though this result may not be attained till more or less marked failure has occurred on many occasions. What can guide these endeavours to perform new movements save sensory impressions, actual or revived? What is the result of this concentration of attention upon present and revived sensory processes? This last question cannot be answered definitely and in detail, but seeing that one result of practice is to make the new movement after a time quite easy of execution, and that further practice still causes it to recur with such facility that it may be fully entitled to take rank as an 'ideo-motor' or even as a 'secondary automatic' movement, we are fairly entitled to conclude, that one of the hidden effects whose existence we can only infer has been the laying down of beaten paths for efferent stimuli, from the sensory centres which have been concerned in guidance (the stimuli in question being in part, at least, the molecular movements occasioned by the revived activity of the sensorial centres) to the particular combinations of motor nerve mechanisms whose excitation is needful for evoking the movements in question.

But if it be assumed that this is what occurs when, by dint of long practice, an at first difficultly-executed voluntary movement becomes, in process of time, a movement so easy of execution as to recur independently of conscious attention,

with machine-like regularity, three important consequences follow:—

In the first place, it seems to afford an organic proof that even as in ideo-motor actions, so in voluntary movements, the immediately evoking stimuli flow out from the sensory centres concerned with the production of such movements—the voluntary movement grows into the ideo-motor movement, and then unmistakeably the guidance is wholly through the sensory centres, for then (as we have seen in the case of a simple reflex movement) the line of least resistance for molecular movements from the sensory cells is through certain new communicating fibres bringing them into relation with definite groups of motor nerve mechanisms.

Secondly, it seems clear that the same motor mechanisms must be concerned with the production of the new voluntary movements as with the ideo-motor or secondary automatic movements into which they become converted at a later date. We have to do in these two sets of cases with differences in the degree of perfection of the nervous mechanisms, and with different degrees of perfection in the functional and structural relations between the sensory and the motor mechanisms especially, rather than with an alteration in the position in which the movements are, so to speak, organised. It is, therefore, in my opinion, a fundamental error to look for special voluntary motor centres The strictly motor side of voluntary motor mechanisms should be identical with, or lie side by side with, the strictly motor side of "ideo-motor" or "secondary-automatic" mechanisms of the same type.

Thirdly, we may safely conclude, that when once the ways or beaten tracts have been laid down by which certain sensory departments are connected with certain motor mechanisms for the performance of voluntary movements, the former may be incited to renewed (or ideal) activity, and may be followed by appropriate responsive movements, almost if not quite independently of, and certainly without any need for, Consciousness as an attendant of such revived sensorial activity: in other words, when once the internuncial tracts have been clearly established from cortical sensory centres to motor mechanisms, it is not in the least necessary that Consciousness should be an appanage of this revival, since even the unfelt recall by associa-

tional processes of activity in the guiding sensory centres, may by causing an outflow of molecular movements, now suffice with machine-like regularity to evoke the accustomed motor reactions, as in the case of a skilled dancer or a skilled player upon a musical instrument.

Sensations Resulting from Movement: Kinæsthetic Impressions.

Before entering into any details concerning the sensory guidance of movements in general, something requires to be said about one particular class of sensory impressions which are of great importance in this relation. I refer to the body of sensations which result from or are directly occasioned by movements. This constitutes a complex of impressions which, for the sake of convenience of reference as well as for the purpose of indicating their common functional relations, I have proposed[1] to include under the designation *Kinæsthesis*, or the "sense of movement," perhaps I ought rather to have spoken of "sensations of movement," as Wundt does,[2] but the former term is more in accordance with those already in use in connection with this subject (e.g., "muscular sense," and "sense of force"). Impressions of various kinds combine for the perfection of this "sense of movement," and in part its cerebral seat or area corresponds with the sense of touch. Thus, under it are included, as its several components, cutaneous impressions, impressions from muscles and other deep textures of the limbs (such as fasciæ, tendons, and articular surfaces) all of which yield conscious impressions of various degrees of definiteness; whilst, in addition, there seems to be a highly important set of unfelt or but little felt impressions which guide the volitional activity of the brain, in ways hereafter to be defined, and which serve to bring it into relation with the different degrees of contraction of all muscles that may be called into action.[3]

[1] 'The Brain as an Organ of Mind,' 1880, p. 543.

[2] Wundt says:—"Les sensations du mouvement, comme nous avons montré précédemment, sont pour nous *des produits fusionnés complexes*, provenant de sensations d'origine différente" ('Élém. de Psych. physiol.' Trad. franç., 1886, i., p. 421.

[3] I have introduced a qualifying phrase after the word "unfelt" above, because

By means of this complex of sensory impressions we are made acquainted with the position and movements of our limbs, we are enabled to discriminate between different degrees of "resistance" and "weight," and by means of it the brain also derives much unconscious guidance in the performance of movements generally.[1]

Of course it may be easily said, and doubtless will be said, by those who have not yet realized the importance of bestowing special attention upon this complex of impressions, that it is unsuitable to describe as though it were a distinct endowment, the means by which we receive and appreciate a group of impressions having such diverse sources of origin. This mere technical or formal objection seems to me, however, to have little weight, when we consider that from a functional point of view they constitute a group of impressions altogether apart, recurring with extreme frequency, and always in more or less similar combinations, during almost every hour of our waking life—subserving also, as we hope hereafter to show, a most important purpose. I think, therefore, we are warranted in speaking of the reception of this group of sensations under the name of kinæsthesis, or the sense of movement. There will certainly be a real convenience in being able to allude to such impressions briefly, as 'kinæsthetic impressions.' It is confessedly a mixed group partly "intrinsic" and partly "extrinsic" in their origin.

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on reflection I think I have been wrong hitherto in saying that "muscular sense" impressions are wholly unfelt. There must be a kind of consciousness associated with them if, as seems now to be established, our knowledge of the position of our limbs, as well as of differences in weight, is in the main due to "muscular sense" impressions.

[1] These impressions are almost always closely linked with others of a tactile, visual, or auditory order, so that their associated ideal recall presents no sort of difficulty, and the question whether, when recalled, they reveal themselves in consciousness or not is one which has no sort of importance for, as Ribot says, consciousness "n'est cause de rien." Writing in the 'Revue Philosophique,' June, 1884, p. 639, L. Manouvrier pointedly illustrates this in the following manner: "En son absence, les cellules cérébrales peuvent être le théâtre d'opérations très parfaites auxquelles peuvent succéder des mouvements très bien appropriés et coordonnés, tout comme s'il y avait eu production de conscience. La seule différence est que le cerveau sert alors de substratum à ces opérations nerveuses sans le connaître, tandis que, dans l'état opposé, il les subit consciemment, voilà tout."

From one point of view, especially, important differences separate this synchronous and fused group of impressions from all other sensory impressions—differences to which it will be as well at once to allude.

Ordinary extrinsic sensorial impressions commonly play the part of instigators to movement. Thus impressions of smell, sight, hearing, touch, and taste are either the immediate or the remote instigators of the great majority of the movements executed by animals.

The movements so stimulated are in almost all cases of a more or less purposive type, directed, that is, to the attainment of some end.

During the whole time that such movements are being evoked the animal is constantly receiving those groups of mixed afferent impressions which we have styled "kinæsthetic," called into existence by the mere movements themselves.

Kinæsthetic impressions are never instigators of movement in the same sense that olfactory impressions may be instigators of movement. Visual impressions and auditory impressions are not only frequent instigators of movement, they are also respectively all-important guides for certain classes of movements. From a functional point of view, kinæsthetic impressions are guides only; these functional uses are, however, co-extensive with movements themselves, since in conjunction either with visual or with auditory impressions they act as guides for all sorts of movements. As it is with visual and auditory, so is it with kinæsthetic impressions, their guiding influence in the production of movements is brought to bear partly under the form of actual sensations and partly under the form of revived impressions (the memories of past activity).

Seeing that kinæsthetic impressions must be as numerous and as endlessly diversified, in their kinds and combinations as movements themselves, it follows that large tracts of the brain ought to be concerned with their registration for future use in the guidance of all kinds of voluntary movements.[1]

[1] I purposely leave out of account for the present the fact, that kinæsthetic impressions enter largely *into the composition of nearly all our visual and tactile* impressions; movements of the eyes, or movements of the hands and fingers, not only vastly increasing the range of possible visual or tactile impressions but also

Except during the last forty years, the occasional references which have from time to time been made to kinæsthetic impressions have appeared rather in the writings of philosophers, than in those either of physiologists or pathologists. Yet the first mention of such impressions goes back, according to Sir William Hamilton, to a rather remote past. He tells us that two Italian physicians, Julius Cæsar Scaliger, in 1557, and Cæsalpinus of Arezzo in 1569, quite independently of one another, were the first to recognize and definitely state that the exercise of our power of movement is the means whereby we are enabled to estimate degrees of "resistance," and that by a faculty of "active apprehension" which was by them contrasted with touch as "a capacity of sensation or mere consciousness of passion." These early references to such an endowment, like those of Maine de Biran and Sir William Hamilton himself, have for the most part supposed the existence of a separate faculty or endowment associated with volition, or the mere will to move, to which such names as the "sense of effort," the "sense of force" or the "locomotive faculty" have been given—agreeing very closely with what Wundt has since termed the "sense of innervation."

Some of the causes why physiologists should for so long have paid but scant attention to this class of impressions may be thus enumerated :—

(1) The most typical and important group of kinæsthetic impressions, viz., those derived from the muscles themselves, belong like visceral impressions, to the class of "intrinsic" sensations, which, as a whole, receive but little of our conscious attention under all ordinary conditions of life. These are "means" rather than "ends," and consequently soon become sub-conscious modes of activity.

(2) These impressions are not directly concerned with the organism's life of relation—that is, they do not directly

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entering as it were into their very structure, and thereby enabling us to recognise and judge what philosophers call the primary qualities of matter, viz., solidity, extension, figure, etc. I also omit further mention of the fact, that kinæsthetic impressions likewise act as guides in the great class of reflex movements which are produced independently of the cerebral hemispheres, by the mesencephalon and cerebellum, as well as by other sensori-motor couples of lower grade.

stimulate its converse with the outside world. Impressions derived from movement cannot in themselves be, nor are they when ideally revived, first-hand instigators of movement, however much they may aid in the repetition of movements previously effected.

(3) Owing to the nature of this sensory endowment, it is one which cannot be investigated by experiments upon animals. The presence or absence of ordinary sensory endowments may be tested in the lower animals, by looking for the recurrence or not of some particular motor reactions which we know are apt to be excited by the presentation of this or that stimulus to the sense which is being tested. The sense of movement being however a so-called "intrinsic" sense, and not an instigator of movements, cannot be tested in this manner. Indeed it may be safely said that no experiments that can be made upon the lower animals, even upon monkeys, are capable of throwing any decisive and direct light upon the presence or absence of the most important element in this endowment, viz., the impressions emanating from contracting muscles.[1]

The Muscular Sense.

It should be stated here that the announcement of the existence of a "special class" of sensations emanating from muscles, came from Sir Charles Bell. He first postulated the existence of a special endowment, to which he applied the name "*muscular sense,*" whilst the reality of the sensations emanating from muscles was first demonstrated and accurately estimated by the experiments of E. H. Weber,[2] who, however,

[1] Thus it happens, perhaps, that the evidence on which Ferrier relies in support of the notion, that the "muscular sense" was defective in three monkeys operated upon by him (*See* 'Functions of the Brain,' 2nd ed., 1886, pp. 335, 340, 344), is no more convincing to me, than is the evidence of Hitzig and Nothnagel to him, in support of their cortical localisation of muscular sense centres (p. 379). We must have observations on men and women for the solution of this problem, who can *tell* us what they know of the position of their limbs, and of their movements (active or passive), as well as concerning their ability to appreciate differences in weight.

[2] Annotationes anatom. (Progr. collecta.) Proleg. xii. (1831). *Tastsinn und Gemeingefühl.*

spoke of the endowment by which we are enabled to discriminate different degrees of "resistance" or weight, as the "sense of force." E. H. Weber was the first to make definite investigations as to the differences in weight which could be appreciated by the mere tactile sense of contact and pressure whilst the hand was at rest on a flat surface, and, subsequently, to ascertain by careful experiments that a considerably heightened power of discrimination existed when the muscles were called into play—that is, by no longer allowing the hand to rest upon a flat surface, but by slowly moving the arm when different weights were successively placed upon the palm. Numerous comparative experiments of this kind made by Weber, and since confirmed by other investigators, have shown, that the activity of the muscles adds greatly to our ability to discriminate differences in "weight" or "resistance." Thus, by the mere sense of cutaneous pressure it has been found that the addition of one-third of the original weight, whatever it may have been, is needful to produce a perceptibly different impression; while, on the other hand, when muscles are allowed to be called into play the power of discrimination is so greatly heightened that an addition of no more than $\frac{1}{17}$th of the original weight is generally capable of yielding a distinguishable difference in the resulting impressions.

This constitutes, in fact, the physiological proof of the existence in us of a distinct ability to discriminate different degrees of weight or resistance by impressions resulting from various states of tension or contraction in our muscles. This ability is lost in certain diseases, and its absence gives rise to disordered movements when the eyes are closed, as well as to ignorance of the position of the limbs and other related defects.

For the better understanding of this part of our subject it seems best to record here, in sequence, the different cases to which I desire to call attention, for the purpose of illustrating the nature of the defects themselves, as well as the nature of the diseases with which they are most commonly associated.

As samples of this kind of evidence I will first cite a few details (all that I have been able to find) concerning two cases which were reported at a time when no particular attention had been given to such morbid phenomena.

"In February, 1790, a German schoolmaster, after extreme worry, was seized with an insensibility extending over the whole body. Movements were freely executed at all the joints, and all his muscles were entirely under the influence of the will, though the patient had no feeling of having executed movements. He could move his toes separately or together at will, but in order to know whether the movement had really taken place he was obliged to assure himself by means of his eyes. He walked quite easily, though it seemed to him as if he did not make use of his own legs."[1]

Demeaux[2] gives details concerning a woman suffering from hemi-anæsthesia, which show the complete loss in her of the sensations coming from muscles, as well as of all other modes of sensibility, superficial and deep, in the affected limbs. He says:—"She put her muscles in action under the influence of her will, but she had no consciousness of the movements which she executed; she knew not what was the position of her arm—it was impossible for her to say whether it was extended or flexed. If one told the patient to raise her hand to her ear, she executed the movement immediately; but when my hand was interposed between her own and the ear, she was not conscious of it; if I stopped her arm in the midst of its movement, she did not become aware of it. If I fixed, without allowing her to be aware of it, her arm upon the bed and told her to raise the hand to her head, she strove for an instant and then became quiet, believing that she had executed the movement. If I induced her to try again, showing her that her arm had remained in the same place, she attempted to do so with more energy, and as soon as she was compelled to call into play the muscles of the opposite side [of the body], she recognized that the movement was opposed."

In these cases the so-called "muscular sense" was clearly absent, and so were all kinæsthetic impressions in the affected limbs, leading to an ignorance of their position and movements. Details will now be given concerning another very remarkable case, of a somewhat different type, which was examined with great care and reported at length by Landry,[3] in his interesting "Mémoire sur la paralysie du sentiment d'activité musculaire."

The patient was a physician, fifty-five years of age, who, from Landry's account, I judge to have been clearly suffering from

[1] Reported in Hufeland's 'Journal,' and quoted by Bellion in his 'Recherch. sur la Pathol. et Physiol. des Sens. tactiles,' Thèse de Paris, 1853, p. 46.

[2] 'Des Hernies Crurales,' Thèse de Paris, 1843, p. 100.

[3] 'Gaz. des Hôpitaux,' 1855, Obs. III., p. 270.

locomotor ataxy of an unusual type. In regard to his power of executing movements with his eyes open and closed respectively, and as to his knowledge of his movements and of the different degrees of tension in his muscles, the following quotations may be made:—

"Voluntary contraction seemed to have lost nothing of its energy. When seated or in the lying posture he easily elevates his lower limb and maintains it elevated for a long time without apparent fatigue, only the limb is the seat of oscillations which he always in part controls when he sees them. He has no idea of the more or less extensive and violent passive movements which his limbs are made to undergo. Active movements are not even appreciated as soon as he ceases to watch them. Thus, after having made him close his eyes, if he is asked to move one of his lower limbs in whole or in part, he does it, but cannot say whether the movement executed is great or small, energetic or feeble, or even whether it has really taken place; and when made to open his eyes whilst he is moving his leg from right to left, for example, he declares that he had only a very inexact idea of this action. In the same way if after having specified to him some aim to be accomplished, and having made him measure the distance with his eye, he is told, without looking, to bring his foot to the spot, it remains on this side of it or goes beyond without his suspecting it, or if he succeeds it is only by chance. On the contrary, when he watches the movement of his foot he easily places it correctly. . . . In fact, when he cannot see his limbs, he is no longer conscious of their existence—he is ignorant of their position. When in his bed he loses them, so to speak, and has to search for them with his hands. In the sitting posture, he often seeks to extend or to flex them when they are already in these positions. If, having the wish to execute a movement, I prevent it, he does not perceive it and attributes to the limb the position which he had intended to give to it. He neither appreciates the resistance one opposes to his movements, nor weights with which one charges his limbs. He easily raises a very heavy object when he has estimated its weight by sight; but if he is not permitted to judge of this previously, he does not know how to apportion his effort to its weight, and the muscular contraction is either too great or decidedly too little.

"In the upper limbs there are almost the same disorders: ill-co-ordinated and badly measured movements; defective appreciation of passive movements, and even of active movements when the patient does not see them; but faculty of co-ordinating and of measuring his movements when he calls to his aid his sense of

sight; great energy of muscular contraction; integrity and rapidity of each isolated movement of the fingers, of the hands, of the forearms, and of the arms; impossibility of appreciating weight or resistance; sensation of extreme lightness of the hands, etc. Prehension is much altered; the patient seizes an object clumsily, and only succeeds in seizing it better when he attentively watches his fingers. He can no longer write. As soon as his attention is relaxed he lets objects fall which he may have been holding, without perceiving that their weight has ceased, or that his fingers are extended. Everything appears to him without weight. He can neither appreciate the thickness nor the size, nor the form of bodies which one makes him touch, or rather almost always attributes to them a form and a size almost identical—he describes them as cylindrical or round, and of about two centimètres in thickness. If, after having made him close his eyes, one takes from his hand an object which he is holding, he does not perceive it, and continues to maintain the position he had taken in order to hold it, believing that he feels something of the same shape and volume. The same thing happens if, equally without his knowledge, one has completely opened his hand; he believes it to be still closed and filled by an object whose form and size he judges as if he had never ceased to hold it. He does not perceive the resistance which is opposed to the movements of his fingers and hand, and often thinks that he has executed a movement when he has been prevented from doing so. He cannot judge of the consistence of bodies, to which he attributes without discernment either hardness or softness. When one plunges, without his knowledge, one of his fingers in water, he perceives the coldness very well, but when he is asked to move his finger about, he thinks he moves it in air and does not perceive the resistance of the liquid.

"His movements have, as I have said, a great irregularity; but all, even the most delicate movements of the fingers, are executed with the greatest facility. When he looks at them one can only prevent their flexion with difficulty, and he can press one's hand vigorously. If he ceases to see, he continues to make efforts to flex his finger or his hand when opposed, but he does not know how to apportion his contraction to the resistance; he also presses the hand very softly, as if there were a real loss of power. With his eyes open, he easily opposes the thumb to each of the other fingers; with his eyes closed, the movement of opposition occurs, but the thumb only by chance meets the finger which it seeks. With his eyes open he is able, without hesitation, to bring his two hands together; but when his eyes are closed his hands seek one another in space, and only meet one another by chance.

The fingers can no longer be regularly interlocked. There is not the least tremor of the hand."

"*Condition of cutaneous sensibility in the four limbs.*—Sensations of contact preserved but obtuse; M. X. feels quite well when he is touched, but he cannot say with what kind of object. Thus he cannot decide whether it is with wool, with wood, or with the observer's hand. He no longer feels tickling. He is able perfectly to specify the precise point at which he is touched, unless the body with which the contact is made covers only a very small area of skin, as, for example, the blunt point of a needle. Sensations of temperature intact; sensations of pain much exaggerated."

Landry gives two other cases very similar to the above, but I will next quote a few details concerning a very remarkable case which, in one important respect, stands in marked contrast with those that have gone before, and more especially with the two cases which will follow—I mean, as regards the patient's ability to execute precise movements when the eyes were closed. This is a case in which a more or less general anæsthesia existed for over thirty years, and the man was repeatedly examined by many trustworthy observers. The record of the case was published by Spaeth,[1] and the autopsy was fully described by Schueppel.[2]

Remigius Lens, aged forty-two, in the year 1862, has suffered for twenty years with anæsthesia of the hands and arms, which rapidly became severe; for six years similar troubles have existed in the lower extremities. Present condition: upper extremities wholly anæsthetic; on the soles of the feet the sensations of touch, pressure, and pain are entirely extinct, and in the legs considerably diminished. *He falls when his eyes are closed.* In the dark, when in bed, he feels as if floating in the air, as the anæsthesia extends to the trunk.

March, 1864.—Sense of pressure in the upper extremity, and the sense of force, entirely extinct. Sense of position of the upper extremity and of passive movements of the latter completely extinct. Movements of the upper extremity powerful and perfectly correct; the patient eats alone, dresses himself, etc., as far as he can direct his acts with his sight. When the eyes are closed, the hands are moved nearly like those of a blind man. In the lower extremities, besides the cutaneous anæsthesia, there is

[1] 'Beitr. zur Lehre von der Tabes dorsalis,' Tübingen, 1864.
[2] 'Arch. d. Heilk.,' Bd. xv., 1874, p. 44.

complete loss of the sense of passive movements and of the position of limbs. In spite of this the patient can walk without support, quite fast and securely, for a good distance. If he is asked to raise his foot to a given height while his eyes are shut, he accomplishes the act by a perfectly quiet and suitable motion.

June, 1872.—Sensibility continues the same. When the eyes are shut he has no idea at all of the position of his limbs, and, if standing falls. He can still walk clumsily, but not atactically. He can perform all desired actions with his arms, as long as he can see them.[1]

This patient seems to have had decidedly more power of executing accurate movements when the eyes were closed, than is commonly met with in such cases. But then the anæsthetic condition of the arms had lasted for twenty to thirty years when the results above recorded were obtained, so that ample time had elapsed to permit his nervous system to accommodate itself to its altered conditions, and so to gain a power of executing voluntary movements with closed eyes, which probably did not exist at first in this patient, in whom "muscular sense" impressions appeared not to reach the cerebral cortex, however it may have been with lower centres. This is certainly an altogether exceptional case.[2]

Duchenne's attention seems to have been attracted to the effects of loss of the "muscular sense" very shortly after the first cases were published by Landry.[3] A short paper from him, entitled "Usages de la sensibilité musculaire" appeared in 1853,[4] which two years afterwards was reprinted and added to in his work "De l'électrisation localisée" (p. 410). Here Duchenne points out that such cases as I have above referred

[1] Abstract quoted from translation of Ziemssen's 'Cyclopædia,' vol. xiii., p. 89.

[2] Yet we find Dr. Ferrier relying upon it, in spite of all other evidence to the contrary, apparently as sole support of a view, which will assuredly find no general acceptance, to the effect that a "limb can be moved freely and forcibly and directed without uncertainty, for volitional purposes," when the eyes are closed, "in the entire absence of any sense of movement" (*loc. cit.*, p. 65). In regard to that point I would refer him to the cases of Landry, as well as to those now about to be recorded from the observations of Duchenne, Briquet and Bazire (pp. 16–20).

[3] Archiv. génér. de Méd., 1852. Other cases were recorded in 1853 by Bellion (Thèse de Paris) 'Rech. histor. sur la pathol. et la physiol. des sens. tactiles.

[4] 'Moniteur des Hôpitaux.'

to (excepting the last, which, of course, appeared after the date of his work) constitute only one category of those in which there is paralysis of what Landry termed "le sentiment d'activité musculaire." He says:—"In the second category, which is much less numerous, *the patients when similarly deprived of sight lose the faculty of executing the simplest voluntary movement.* If they are bid for example, to open or shut the hand, flex or extend the forearm, in a word, whatever movement one asks them to make, the muscles which ought to enter into contraction remain inert, notwithstanding all the efforts of the will. One only observes sometimes certain irregular movements, slight in extent, weak, and different in kind from those that they wish to execute—movements of which they have even no knowledge. Nothing can describe their astonishment when they perceive, after the experiment, that their limb has remained in the same situation, when they thought they had made it execute a movement. Their surprise is all the more great, since they can execute this same movement with rapidity the instant that they are permitted to look at the limb."

In confirmation of these statements Duchenne gives a detailed account of a patient in 'la Charité' under the care of Briquet, whom they conjointly submitted to repeated careful examinations.[1] The patient was an hysterical girl who was suffering from complete anæsthesia, superficial and deep. She presented all the same kind of phenomena as were seen in the cases already recorded, that is to say a lack of knowledge as to whether a movement which had been willed had been executed or not (necessarily, therefore, an ignorance of the extent of her movements and of the position of her limbs), together with a total inability to appreciate degrees of resistance. In addition, however, there were new peculiarities concerning which the following quotations may be made.

"There was also another phenomenon which M. Briquet and I observed in this case of general and profound insensibility: that is, one could violently strike her limbs, shake them violently, and change their place, without her having any knowledge of it. . . .

[1] *Loc. cit.* p. 417.

On devoting myself to the examination of this patient I found that she presented in the highest degree the phenomena which constitute the special object of this article. Thus having stooped in such a manner as to prevent her seeing her hand at the moment when I told her to close it, the hand remained motionless though she thought she had closed it; and, whilst I was making her extend and flex the forearm upon the arm, having turned her attention away from this limb the movement was immediately arrested—the limb remaining in position as if it had been tetanised. I should add that the patient, whom I had seen for the first time, was quite ignorant of what I sought to establish. . . . But here is another experiment which shows, in addition, that the action of the will in combination with the sense of sight was necessary also for the cessation of a contraction once produced. If after having made her squeeze the hand, she is prevented from seeing it, and told to cease all effort, one feels that the contraction of the flexors continues, and it is necessary to employ considerable force to open her hand. Or, if after having made her flex the forearm, one prevented her seeing it the forearm remained in a state of flexion, and it was necessary to employ a pretty strong force to extend it (it must be recollected that the patient, deprived of all sensibility, had no consciousness of the movements which were impressed upon her limbs").

"Here, again, is another experiment which shows that it is not sufficient for the patient merely to be able to see in order that the movement should be obtained, but that it is also necessary for her attention to be fixed upon the limb about to be called into movement. Having placed the patient's hands sufficiently close to one another so that she was able to see them both equally well, I asked her to shut them and to open them both at the same time. The flexion was executed, but alternately on the two sides; and it was the same in regard to the extension. She was not able to contract homologous muscles at the same time, whatever effort she made to obtain such a result. One could see that during the contractions she alternately fixed her attention upon the hand about to be called into movement. It was no longer possible for her to flex or extend simultaneously both forearms." This patient remained under observation for many months without any notable change in her condition.

The account given by Duchenne of this remarkable case was subsequently entirely confirmed by Briquet. He also holds that this extreme condition of anæsthesia of the muscles

is extremely rare. He, however, gives the details of another case,[1] just as extraordinary as that recorded by Duchenne, this patient having been under his care for nearly twelve months in 'la Charité.' Here are a few quotations extracted from his report:—

The patient was a girl, 21 years of age, suffering among other things from complete loss of taste, from noises in the ears, and from amblyopia especially on the left side.

"The skin of the whole periphery of the body is completely insensible; the patient absolutely does not feel anything which she touches.

"The muscles of the limbs do not feel pressure; they require to be pressed strongly against the bones before the patient feels anything. Passive movements are not at all felt, so that the patient has no consciousness of them if sight does not intervene.

"In short, the anæsthesia of the surface of the body is so extreme that, having bandaged her eyes, the patient has been taken from her bed with only her night-dress on, placed upon the floor of the ward where she has been left a few moments, and then replaced in her bed, without her having any consciousness of what had been done. The patient describes her condition by saying that she is like a balloon suspended in the air. She has only the sense of sight, which is weak, and that of hearing, which is just as bad.

"The muscles of the upper extremities are notably weak, nevertheless the patient can sew pretty well; she moves her fingers and hands well, but *if one prevents the intervention of sight no movement is any longer possible: whatever may be the efforts of the will, there is complete immobility.*

"The lower extremities are still more feeble; the patient can, whilst in bed, execute some movements of the whole limb, but she cannot move the toes, and when she is placed on her legs they immediately double under her, and there would inevitably be a fall [if she were not supported]."

After she had been in the hospital about four months this patient was in some respects better, she could for instance maintain herself in the standing position when supported on both sides, but as regards her knowledge of passive movements, and of the position of the limbs, there was no improvement whatever.

Fortunately I have been able to find the record of another

[1] 'Traité de l'Hystérie,' Paris, 1859, p. 304.

case recorded by Bazire,[1] very similar to those reported by Duchenne and Briquet. Only here we have to do with hemianæsthesia rather than with general insensibility, and there is the important fact that it occurred in a man rather than in a hysterical girl, and probably as a result of some slight organic lesion. The actual inability to move when the eyes were closed was here, moreover, limited to the lower extremity; though the power of moving the upper extremity under the same conditions was much more than usually affected. This case is in marked contrast with the ordinary run of cases of hemianæsthesia, in which there is generally no very appreciable loss of "muscular sense."

"W. P.——, aged 43, married, a plumber and gas fitter, was admitted into the Westminster Hospital, under Dr. Fincham's care, on April 25, 1865. He is tall, fairly nourished, with a sallow complexion, and there is a faint blue line along the edge of his gums. He has never had gout, rheumatic fever, or syphilis. A year ago he had an attack of lead colic, followed by dropping of the left wrist, which only lasted a few days.

"*Present state:*—There is complete *analgesia* of the whole left half of the body, exactly limited to the median line—namely, of the left half of the head, face, tongue, palate, neck, trunk, and penis, and the left arm and leg. Pricking and pinching, except in the spots to be presently mentioned, are obscurely felt as a mere contact, and many seconds after the impression is made. The left eyeball is so insensible to pain that the patient rubs it with impunity. The left half of the tongue cannot distinguish sapid substances, and the patient complains of a sensation of heat and dryness, and occasionally of pins and needles in that side of the organ. Instead of analgesia, there is tenderness on pressure in front of the left elbow-joint, and again near the lower edge of the deltoid. Differences of temperature are more acutely perceived on the affected rather than on the healthy side. There is nearly complete *anæsthesia* of the left half of the body, for when any point is touched on that side, the patient becomes conscious of it, only after an interval of several seconds, and besides, localizes the impression erroneously. He states that he feels as if through a thick layer of flannel or wool. He does not know the position of his left arm or leg, if he does not see it. *If, when his eyes are shut, he be asked to touch the tip of his nose with his left hand, he visibly makes considerable efforts, but his hand, which is raised with great difficulty and slowness,*

[1] Translation of Trousseau's 'Lectures,' 1866, p. 213.

either stops at a certain height, or goes to one side of the head, never succeeding in touching the nose. The movement is slow and hesitating, never abrupt or jerked. *When his eyes are shut, he cannot make the least movement with his left leg.* When he walks, he keeps his eyes fixed on the ground immediately before him, not on his legs. His gait is somewhat uncertain and unsteady, but not markedly so. *He cannot walk with his eyes closed;* he cannot stand, even with his eyes open, when his feet are closely approximated, and he looks straight before him. *If, while his feet are wide apart, he shuts his eyes, he immediately oscillates from before backwards, and threatens to fall down.* He says that he then feels as if he had only one leg.

"There is no real *diminution of motor power* at present, at least beyond a slight depression of the left angle of the mouth, and a scarcely perceptible deviation of the apex of the tongue to the left side. There is no difference of size between the muscles of the right and left limbs; electro-muscular contractility is perfect on both sides, but electro-muscular sensibility is almost *nil* on the left. None of the senses are affected, except *taste* in the left half of the tongue. Vision is good; the left pupil is, however, appreciably smaller than the right. Hearing is perfect on both sides. The intellect was never affected; memory is very good, and the man gives an excellent account of himself. There has never been any headache, but more or less giddiness throughout. Articulation thick and embarrassed, probably owing to the numbness of the left half of the tongue and soft palate; but the faculty of language is unimpaired. Appetite good; digestion easy; bowels at present regular, but were formerly very costive. The bladder was never affected.

"*Mode of Attack.*—The patient's illness dates from the beginning of September, 1864. It set in suddenly, without any premonitory symptoms, about seven o'clock one morning, with a sense of chilliness and numbness all down the left half of the body. He was not, however, prevented from attending to his usual occupation, until three weeks afterwards, when the numbness was replaced by complete insensibility. There was also some motor paralysis at first, as it appears from his statement; for he affirms that there was real and considerable weakness of his left arm and leg, that his left cheek was pendulous, and that the right angle of his mouth was pulled upwards and outwards whenever he spoke or laughed. Until he was examined by Dr. Fincham, he had not discovered his inability to move his left arm and leg unless he looked at them. Under the influence of faradization, and the administration of iodide of potassium for a short time, and afterwards of hypophosphite of soda, he gradually improved."

So far the cases to which I have referred have belonged to one or other of two categories, that is they have been either (*a*) cases of locomotor ataxy, or (*b*) they have been cases in which there has been loss of sensibility, deep as well as superficial, either unilateral or general. It is, indeed, now well known that these are the two forms of disease in which we are entitled to look very frequently for some loss or defect in kinæsthetic impressions generally, and of those pertaining to the "muscular sense" in particular. It is, however, also well known that all kinds of kinæsthetic impressions are by no means equally or necessarily affected in these two diseases. In each of them, for instance, ordinary cutaneous sensibility, and possibly even deep sensibility, may be gravely impaired or lost, when there is comparatively little loss of special "muscular sense" impressions.

Thus in locomotor ataxy it is now well-known that there is no regular parallelism between the loss of ordinary modes of sensibility, and the loss of special "muscular sense" impressions. In some rare cases of this disease there may be very little loss of ordinary modes of sensibility, and yet a marked deprivation of "muscular sense" impressions. The first case recorded in Landry's memoir seems to have been, in its early stages a well-marked one of this kind, and Trousseau said that out of about fifty cases of locomotor ataxy he had seen three of this latter type. This is a class of cases, however, about which we want further precise information.

Similarly, in regard to hemianæsthesia, it is now well known to be quite exceptional to meet with such cases as those recorded by Demeaux (p. 11), in which there was complete loss of special "muscular sense" impressions. The rule has been, for instance, with the hemianæsthetic patients which have been so thoroughly investigated by Charcot at the Salpêtrière that although there has been complete loss of tactile sensibility, and usually absolute insensibility to pain in the skin and all other sensitive structures on the affected side, together with slight paresis of the affected limbs, the so-called "muscular sense" has been nearly always preserved. Their ability to perform even complex muscular movements when the eyes are closed has remained quite intact. This

was well seen, for instance, in the case of one of his hemianæsthetic patients who was hypnotised by Charcot in the presence of a party of distinguished observers when the following phenomena were witnessed.[1]

"At 10.7, the patient being asleep, Professor Charcot told her to rise and take a chair. She did so, her eyes being closed and her eyelids tremulous. Having seated herself he told her to write her name. Pen, ink, and paper being furnished her, she sleepily wrote her own name, and afterwards, when ordered, Professor Charcot's, *her eyes remaining closed the whole time.* Whilst writing the skin over the right wrist was transfixed by a thick needle, but the patient appeared quite unconscious of the operation, continuing to write with the needle *in situ.* It is to be remarked that during the mesmeric state, the patient is anæsthetic on both sides of the body; whilst, in the waking state, it is only the left side which is anæsthetic. At 10.10 Professor Charcot told the patient to begin to sew. A half-hemmed towel was handed to her, and she at once commenced to sew with great dexterity and rapidity, co-ordinating admirably the movements of the two hands. The patient was then told to rise and go into an adjoining room used for photography; she did so, and on her way, having to descend a step, she walked with caution and safety, *her eyes being still closed.*"

Phenomena of the same kind, as well as others, were shown to Prof. Rouget of Montpellier and myself on the following day by Prof. Charcot, demonstrating that even in well-marked cases of superficial and deep anæsthesia, there may be no loss of the muscular sense or difficulty in executing even complicated voluntary movements when the eyes are closed. In a small minority of cases of hemianæsthesia, however, it is not so, and then we have to do with such phenomena as were met with in the typical case recorded by Demeaux if not such extreme results as those met with in the cases of Duchenne, Briquet and Bazire. We stand much in need of further records concerning this small minority of cases.[2]

[1] As recorded by Dr. Arthur Gamgee in 'Brit. Med. Journ.,' Oct. 12, 1878, p. 545.

[2] Such facts have been strangely lost sight of by Prof. Ferrier when seeking to interpret the results of his experiments upon the cerebral cortex of monkeys. It is difficult to understand, for instance, how he can make such statements as these ('Functions of the Brain,' 2nd ed., p. 64):—"There are certain clinical

Other cases, however, in which there is a marked defect in "muscular sense" impressions, appear to exist which cannot be included in either of the previous clinical categories. We must regard them as constituting a class apart, (*c*) the nature and clinical character of which have hitherto been extremely ill-defined. Landry recorded, but unfortunately in abstract only, two such cases. Brief though the details are, it will be well, however, to reproduce them here, as they are cases in which tactile sensibility was either unimpaired or but slightly affected.[1] The nature of the first case, more especially, is very obscure, owing to insufficiency of clinical details.

"Obs. IV.—The woman Reine, 42 years old, a seamstress, of a nervous lymphatic temperament, but strongly built, entered on March 20, 1852, the Beaujon Hospital (under the care of M. Sandras). After having experienced, in the course of the year 1849, headaches accompanied by giddiness, subjective noises, dizziness, and loss of appetite, she began to experience tinglings with a sensation of numbness in the upper and lower extremities;

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facts which would seem to show that the sensibility of the muscles, and the muscular sense may continue though cutaneous sensibility is abolished. But, though the possibility of this cannot be denied, the actual existence of such a condition is far from being satisfactorily proved. Much of the evidence adduced is extremely unsatisfactory, and there is reason to believe that tactile sensibility is not entirely abolished, though there may be insensibility to pain and temperature, in the cases where the muscular sense really continues." Further on, after quoting some details concerning the rare and exceptional case of hemianæsthesia recorded by Demeaux, he says (p. 325), "These facts show clearly that the same condition which abolishes cutaneous sensibility, also entirely annihilates the so-called muscular sense," adding, "from such and similar cases, many of which I have myself seen and investigated, and multitudes of which are to be found in medical literature," etc. I should be extremely glad if Prof. Ferrier would give us some references to other cases like those of Demeaux, "multitudes" of which, as he says above, are to be found in medical literature. What he writes also on p. 344 (*loc. cit.*), seems to show that he considers it to be the rule that "muscular sense" is lost in cases of cerebral hemianæsthesia.

[1] These two cases, as well as those which follow (recorded by Zenner and Horsley) ought to prove interesting to Dr. Ferrier, considering the very positive views which he has recently expressed. Thus, he says ('Functions of the Brain,' 2nd ed., 1886, p. 380):—"There is no necessary connection between the power of directing movements and the muscular sense, as has been erroneously assumed by Brown Séquard and others. Loss of the muscular sense never occurs without general anæsthesia of the limb. No one has even furnished the slightest evidence of impairment, or loss of the muscular sense apart from profound impairment or total abolition of the common sensibility of the limb." Each of these statements is, in my opinion, thoroughly inaccurate.

at the same time her sight failed a little. In 1850 the lower extremities appeared to lose power, and her gait became staggering. From that time a paralytic affection developed which made continual progress.

"On her entry into the hospital (March 20, 1852), walking could not be accomplished without the aid of a stick. There was great difficulty in rising and in preserving her equilibrium; irregularity in the movements of the lower limbs; a tendency to assume an accelerating gait; power of executing all movements, which were extensive and energetic: *unconsciousness of passive movement; imperfect appreciation of the position of the lower extremities and of the extent of their active movements; defective measuring of movements when the eye does not watch them*, etc. A slight feebleness of the hands. *Sensibility absolutely intact.* Micturition and defecation normal. Integrity of intelligence and of all the senses excepting sight which is much enfeebled. No local morbid sign on the side of the nervous centres. . . . In February, 1853, there was an aggravation of all the symptoms. No relief had been derived from various kinds of treatment."

There is also no sufficient clue as to the nature of the next case. It occurred in a hysterical patient; though it seems very possible that it may have been due to a tumour in the right Rolandic area.

"Obs. V.—Angélique M. . . ., 46 years of age, a worker in furs, strongly built, but actually in a profoundly cachectic condition, of a nervous lymphatic temperament, entered, on Dec. 9, 1851, the Beaujon Hospital under the care of M. Sandras.

"This patient, subject to hysterical attacks for nearly twenty years, perceived at the end of 1849 that the left hand was becoming weak and numb. A paralysis of the whole limb soon developed, characterized by these symptoms: execution easy, though feeble, of all movements of the fingers, of the hand, and of the forearm, but without precision or being properly measured; *defective appreciation of passive movements and of the extent as well as of the energy of active movements; impossibility of appreciating weight.*

"All the functions of the upper limb are profoundly altered, and the patient cannot put it to any use which demands a little delicacy in the movement.

"*Sensations of contact and of temperature preserved;* sensations to pain obtuse and abolished in places. Sight very feeble; all the other senses are intact. No morbid local sign on the side of the nervous centres. Chloro-anæmic cachexia. Hysterical phenomena."

Another of these cases has, however, been recently recorded by P. Zenner[1] in which there is very strong reason for believing that the symptoms were produced by injury to Ferrier's so-called "motor centres" for the arm. The evidence in favour of this localisation is altogether similar in nature to that upon which Ferrier has himself relied, in several cases, in his lectures on the "Localisation of Cerebral Disease."

"A. N., age 23, shoemaker, was wounded during the court-house riot, March 29, 1884. The wound was on the right side of the head and laid bare the bone, on the surface of which a linear fracture, without any depression, was seen. It was made by a ball which had ploughed through the scalp and just grazed the bone. The wound was four inches long, and about two and a half inches from the median line, and would have been equally divided by a line passing from one auditory meatus over the vertex to the other.

"The man was unconscious for some hours after the injury, and there was occasional delirium for a period of two weeks. When consciousness returned it was observed that the left arm was entirely powerless, and that the face was drawn to the right side. No observation of the condition of the lower extremities was made. Shortly after the injury there was loss of sensibility in the hand; a pinch was not felt. From the second or third day, for about a week, there were frequent convulsive movements of short duration, apparently limited to the muscles of the face and unattended by loss of consciousness.

"Within a week power of movement at shoulder and elbow had returned, though the hand and wrist were yet powerless. After a few weeks a paresis of the left hand alone remained.

"I first saw the patient seven months after the date of the injury. The foregoing statements were obtained partly from the family, partly from Dr. N. P. Dandridge, who saw the patient about a week after the wound had been received. I saw the patient three times the latter part of October, and December the 1st, 1884, and May 16, 1885. As my first examination was a hasty one and no notes were taken, I will give a description from notes of my examination on December 1st.

"He is a man of average size, well built, and of good muscular development. On the right side of the head there is a linear cicatrix two and a half inches in length. The direction of the cicatrix is parallel with the sagittal suture, from which it is

[1] 'Journal of Nervous and Mental Disease,' New York, 1886, p. 438.

distant about two and three quarter inches. The central part of the cicatrix, in an antero-posterior direction, is just above the meatus auditorius. Patient does not suffer with headache, or other subjective symptoms, and, in his own opinion and that of his family, his mental powers are unimpaired. There is no impairment of sensation or motion anywhere except in the left upper extremity. He can walk long distances without difficulty, and the face, both in repose and action, shows no motor defect."

"*Left upper extremity.*—Power in the movements at the shoulder, and extension of the elbow about equals that of the right side. Cannot flex the elbow quite as forcibly as the right, but, perhaps, the difference is not greater than could be accounted for by its being the left arm, and its having been used less than the other for some time. Grasp in left hand fair, but quite appreciably less than in the right. But the difference in the power of the flexors of the fingers is more apparent when he attempts to flex one or several fingers separately. Then there is a decided difference in the two hands, the greatest difference being observed in the middle and ring fingers. This difference is also manifested when he holds an object, as a pencil, between his finger-tips. He holds it well with the left hand, but with decidedly less force than with the right.

"Cutaneous sensibility is good everywhere, excepting over the fingers. Elsewhere he feels the lightest touch (though in the left palm it is less accurately localized than in the right), but in the last two phalanges, both in their dorsal and palmar surfaces, he only becomes aware that the parts are touched when decided pressure is made. A small piece of coin, whose exact character is immediately recognized by the right hand, is often not felt at all when placed between the fingers of the left hand.

"*The knowledge of the position of the fingers is impaired.*—This is most marked in the middle and ring fingers. Occasionally he does not seem to know (eyes being closed) that the finger is moved. At other times he mistakes which finger it is. On the right side his knowledge in this respect is perfect.

"Actions requiring some delicacy of movement are performed very awkwardly. He buttons his coat with the left hand with the greatest difficulty.

"The only deep reflex action which could be elicited was a slight movement in tapping the lower end of the radius. The same reflex could not be elicited in the other side.

"A word more as to the improvement of the patient. According to the statement of the family, there was continuous improvement for six months, after which his condition appeared to remain

stationary. I first saw him seven months after he sustained his injury. As before stated, my examination at that time was hurried, and no notes were taken; but my impression is that both the impairment of sensation and muscular weakness were greater than they were at the time of my second examination, some five weeks later. But his condition May 16th (nearly fourteen months after the injury) was in no wise different from what it was December 1, 1884, unless it be that delicate movements, as buttoning his coat, were performed with more ease."

In this case there is strong reason for believing, as Zenner points out, that we have to do with a limited lesion of the cortex in the Rolandic area. The loss of "muscular sense" as well as the defect of tactile sensibility from a lesion so situated would, of course, be a matter of extreme importance. But the evidence in favour of such impairment of the "muscular sense" in particular, as a result of cortical lesions in the Rolandic area, is greatly strengthened by the following cases, extremely important in more ways than one, which have been recorded by Victor Horsley in a communication made by him to the recent meeting, in August last, of the British Medical Association.[1]

CASE I.—James B., aged 22, was admitted into the National Hospital for Paralysis and Epilepsy, under the care of Dr. H. Jackson and Dr. Ferrier.

Past History.[2]—At the age of 7, the patient was run over by a cab, in Edinburgh. He was at once admitted into the Royal Infirmary, under Professor Annandale, who found a depressed comminuted fracture, with loss of brain-substance, in the situation mentioned below. The fragments of bone, etc., were removed, and the wound ultimately healed, although it suppurated freely, and hernia cerebri occurred. The patient was hemiplegic for some time, but gradually (seven weeks) the paralysis disappeared. At about 15 years, the patient began having fits, which were very intermittent. He was admitted into the hospital in 1885, when he had an enormous number of fits, and for some days was in the *status epilepticus*. After discharge from the hospital, he had

[1] *See* 'Brit. Med. Journal,' Oct. 9, 1886.

[2] Owing to the great courtesy and kindness of Prof. Annandale, who supplied Dr. Ferrier with an elaborate description of the case while under his care, I am fortunately able to furnish an accurate history of the injury causing the epilepsy. (V. H.)

no fit for seven weeks, at the end of which period they returned, and for three days before admission he was again in the *status epilepticus*.

Present state.[1]—On the left side of the vertex of the head (the exact site, as determined by measurement, being the centre of the upper third of the ascending frontal convolution; that is, posterior to the hinder end of the superior frontal sulcus) there was a quadradiate scar, opposite the centre of which the bone could be felt to be wanting, so as to form an oval opening in the skull, the long diameter of which was about one inch, and parallel to the sagittal suture. Pressure on this scar always gave pain, which was very greatly increased when the patient was suffering one of his paroxysms of fits.

Fits.—The fits, which occurred in batches (at this time the patient had 3,000 in a fortnight), were almost always of the same character, usually commencing in the right lower limb, sometimes in both the right limbs simultaneously. An example of a fit of the first category is as follows:—

"The right lower limb was tonically extended, and the seat of clonic spasm. The right upper limb was then slowly extended at right angles, to the body, the wrist and fingers being flexed; the fingers next became extended, and clonic spasms of flexion and extension affected the whole limb, the elbow being gradually flexed. By this time, spasms in the lower limb having ceased, but those in the upper limb continuing vigorously, spasm gradually affected the right angle of the mouth, spreading over the right side of the face, and followed by turning of the head and eyes to the right."

To sum up, the parts affected were so in the order of lower limb, upper limb, face, and neck; the character of the movements was, first, extension, then confusion, finally, flexion,[2] showing clearly that the focus of discharge was situated around the posterior end of the superior frontal sulcus, this point coinciding, as mentioned above, with that found by actual measurement. Before going on to describe the surgical treatment, it is important to mention that the patient was distinctly hemiplegic, even ten days after the last fit, but he could perform all the movements of the right limbs, though about half as strongly as on the left side, there was no affection of sensation on the right side, while the reflexes, superficial and deep, were exaggerated in both the right limbs.

[1] Only those facts are given which directly bear on the cerebral disturbance.

[2] See a paper by Dr. Beevor and myself, to be shortly published by the Royal Society in the 'Philosophical Transactions.' (V. H.)

Operation, May 25th, 1886.—According to the method described in the foregoing paper, the bone around the old opening was freely removed, the dura mater, arachnoid, and skin being found to form a homogeneous mass of fibrous tissue; the former was raised with the flap. The scar in the brain was found to be highly vascular, of a deep red colour, and about three centimètres long and two broad. The membrane covering the brain around appeared to be very opaque, and the brain of a slightly yellower tinge than usual. The scar, and about half a centimètre of surrounding brain-substance, was excised to the depth of two centimètres. It was then found that the scar-tissue penetrated a few millimètres further into the corona radiata fibres of the marginal convolution. This portion was then removed, and the wound closed. In the removal of the mass, three fair-sized veins, coming, directly from the middle of the area for the upper limb, had to be ligatured, since they passed directly into the scar. The wound completely healed in a week. The tension of serum was twice relieved (once, probably unnecessarily) The most interesting point now to be recorded is, that after the operation the patient was at first completely paralysed in digits of the right upper limb; and for further flexion of the wrist and supination of the fore-arm. Coupled with this motor paralysis, there was loss of tactile sensibility over the dorsum of the two distant phalanges of the fingers. He could not localise the touch anywhere below the wrist within the distance of one internode; finally, he could not tell the position of any of the joints of the digits. Then we have here, apparently, a distinct instance of loss of tactile sensibility and muscular sense, coupled with motor paralysis, all due to lesion of the cortex[1]. It cannot, however, be too clearly understood that it is very possible that some of the fibres coming from the gyrus fornicatus in the corona radiata may very probably have been injured. This condition of motor and sensory paralysis gradually disappeared in the course of the next two months. Up to the present time the patient has had no fits.

Case II.—Thomas W., aged 20, was admitted into the National Hospital under the care of Dr. Hughlings Jackson.

Family History.—There was nothing important, save that a paternal aunt died of consumption.

Past History.—He had had many attacks of pleurisy after the age of 15.

History of Present Illness.—He began, in January, 1884, to have "cramps" in the left thumb and forefinger, these consisting of

[1] By this I mean, of course, the disturbance in the area for the upper limb produced by the ligature of the veins coming from it, as noted above. (V. H.)

clonic opposition of the named digits, and occurring about twice a day for three months. The first severe fit occurred in March, 1884. Spasm spread up the arm, and the patient fell. He had the second in January, 1885. Then followed a series of remissions of the twitchings, until, in August, 1885, another severe fit commenced a series of fits, occurring once or twice a week, until admission on December 4th, 1885. The character of the fits was almost always the same. They began by clonic spasmodic opposition of the thumb and forefinger (left), the wrist next, and then the elbow and shoulder were flexed clonically, then the face twitched, and the patient lost consciousness. The hand and eyes then turned to the left, and the left lower limb was drawn up. The right lower limb was next attacked, and, finally, the right upper limbs. Paralysis of the left upper limb frequently followed a fit. At frequent intervals every day the patient's thumb would commence twitching, but progress of the convulsion could often be arrested by stretching the thumb or applying a ligature. In February and March, 1886, the twitchings frequently commenced in the face, but in April again the thumb was the most frequent seat of origin of the fits.

Present State (much abbreviated). *Motion.*—The grasp of the left hand was 45; of the right, 85. He could perform all movements with the left upper limb, though those of the hand were rather enfeebled. The left thumb was frequently in a state of rigidity, alternating with clonic spasm. (This state could easily be induced by manipulating the thumb.) *Sensation.*—There was no affection, save loss of muscular sense (that is, sense of position, etc.) in the left thumb. *Deep Reflexes* were exaggerated in the left upper limb. The patient frequently had severe headache, beginning at the occiput, and shooting forward, especially to the right parietal region. The *Optic Discs*, examined by Mr. Marcus Gunn, appeared to be normal, though very pink (physiological hyperæmia).

Diagnosis.—In a paper referred to in the foregoing case (No. I.), Dr. Beevor and myself have shown, that the movement of opposition of the thumb and finger can be elicited by minimal stimulation of the ascending frontal and parietal convolutions at the line of junction of their lower and middle thirds. Dr. Hughlings Jackson witnessed one of our experiments demonstrating this fact, and expressed his belief that this patient (Case II.) was suffering from an irritative lesion of unknown nature, situated in the part of the brain thus indicated. Confirmation of this opinion was to hand in the order of march of the spasm, which was in nature and arrangement in exact accord with

the results of the investigations referred to. An exploratory operation was therefore decided upon.

Operation (June 22nd, 1886).—The seat of the lesion having been determined by measurement, the large trephine was applied; and, on raising the dura mater, a tumour came into view. More bone was removed above and in front, so as to completely expose the mass to which the dura mater was adherent. The border of the tumour stood out about one-eighth of an inch from the surface of the brain, and it was much denser than the brain-substance. It appeared to be only half an inch broad, but as the brain-substance all round it for more than half an inch appeared dusky and rather livid, I removed freely all the part apparently diseased. (As is shown in the photograph and specimen, this procedure was fully justified, since the growth spread very widely under the cortex.) Before closing the wound, the centre of the thumb-area was removed by free incision. This detail Dr. Jackson and myself had resolved to carry out in the possible event of there being no obvious gross organic disease, in order to prevent, as far as possible, occurrence of the epilepsy.[1] Numerous vessels were ligatured, especially three or four at the upper border of the growth proceeding from the rest of the cortex, for the movements of the upper limb. The wound was closed as before. Five-sixths of it healed by the first intention in a week, in spite of the fact that there was considerable œdema of the scalp, due to irritation by the carbolic gauze (removed speedily by changing to eucalyptus gauze). The remaining sixth, just at the lower border of the flap, gave way, and healed by granulation, after separation of a small piece of skin at the edge. The after-condition of the patient was most interesting and important. There was, next day, partial motor paralysis of the left side of the face (lower division), complete motor paralysis of the left upper limb, from and including the shoulder. On the 27th June, there was noted left hemianæsthesia to a light touch (sensibility to pain unaltered), localisation of a prick of a pin very deficient all over the left side, perfect on the right, complete loss of muscular sense in the left upper limb below the shoulder. On the second day after the operation, when making an effort to move the left upper limb, the patient suddenly put his hand to the wound, and said he felt a

[1] To discuss this point in detail would entail excessive lengthening of this paper; but I wish to point out that, as strongly urged by Dr. Jackson, the removal of an epileptogenous focus is not only justifiable, but called for. The exact localisation could be ascertained by the use of the induction current, the employment of which means I resorted to for diagnosis nearly three years ago. 'Brain,' Vol. VII., p. 232. (V. H.)

"buzzing" in the head there. When the left upper limb was passively moved, he also complained that pain seemed to shoot up the "bones of the limb," side of the neck, and through the hand to the wound. The deep reflexes were much exaggerated on the left side in both limbs. All the above conditions gradually improved, and at the date of the meeting, the patient had regained everything, except that the grasp of the left hand was not quite so good as before, and the five movements of the fingers remained hampered. Further, the deep reflexes on the left side are at the present time still very much exaggerated. The patient had, in July, a few slight twitches in the three right fingers; none in the thumb or index; no fits since operation. The tumour was composed of dense fibrous tissue, with two caseated foci, microscopical examination proving it to be tubercular.

It is unfortunate that in the first of these cases no observations were made upon the state of the lower extremity in regard to its "muscular sense" impressions. Such cases require to be examined with the greatest care in order to obtain trustworthy information concerning the "muscular sense." We must look therefore for further information in these directions, and no cases will be so important as those in which portions of the Rolandic area have been actually excised by the surgeon. They are veritable experiments, from one point of view, calculated to throw light in directions from which none is to be hoped for from experiments upon animals not endowed with the gift of speech, in regard to the presence or absence of "muscular sense" impressions, and, it should be added, even of tactile impressions in the hand in cases, for instance, where corresponding portions of the Rolandic area have been removed by operation.

A very important paper by Westphal in reference to some of these questions, is to be found in the "Charité-Annalen"[1] concerning a case of wasting disease in the ascending parietal convolution and parietal lobule (though not absolutely limited thereto) in which, in addition to other troubles, there was the association of paralysis with marked loss of "muscular sense," and some diminution in tactile sensibility.

It seems best to defer, for the present, any further remarks

[1] VII. Jahrg., 1882.

as to the paths or cortical termini for "muscular sense" impressions.

Meanwhile, what has already been brought forward will show that three kinds of defects related to one another, it is true, are to be looked for in cases where special "muscular sense" impressions are either absent or defective. These defects are as follows:—

(1) Defective knowledge of the extent of movements executed, either actively or passively, as well as of the position of the limbs, when the eyes are closed.

(2) Difficulty in discriminating differences in weight or degrees of resistance when muscles are called into play.

(3) Difficulty in accurately performing given movements when the eyes are closed.

It is, of course, of some importance to know whether these three kinds of disability are referable to loss of kinæsthetic impressions generally or whether they are specially related to loss of the most important group of these kinæsthetic impressions, viz., those of the "muscular sense."

This subject has already been alluded to in part; it has been stated for instance, that in the majority of hemianæsthetic cases, there is (3) no difficulty in accurately performing movements when the eyes are closed. This is a matter of common observation, but it has been thoroughly established of late years by Charcot and others.

Again, it has been shown more especially by the observations of Leyden[1] and Bernhardt,[2] that the sensibility of the skin may be partially or completely destroyed without appreciably altering (2) the patient's ability to discriminate differences in weights when his muscles are called into play. It may be stated that in applying this test to the upper extremities, leather balls of the same size but differently weighted within with lead may be used, or where these are not to be had, we may roughly test the ability to discriminate differences in weight (the patient's eyes being closed) by placing piles of pence, or books of the same size except as regards thickness, upon the extended palm. In the examination

[1] 'Archiv de Virchow,' t. 47, p. 325, *et seq.*

[2] 'Archiv für Psychiatrie,' iii., pp. 618 and 632.

of the lower extremities different weights may be suspended from the extended limbs. On this subject Bazire [1] has said:—

"Quite recently Dr. Jaccoud has applied Weber's method to the lower extremities, and the results of his experiments, made on twenty-four different individuals, tend to show that it is possible, in health, to distinguish on an average a difference of from 50 to 70 grammes (say about two ounces) between two weights successively suspended from a lower limb. In six ataxic patients to whom this test was applied, the minimum of the difference in weight appreciated by the patient was found by Dr. Jaccoud to be considerably above the healthy average, varying from 100 to 3000 grammes (from 3½ ounces to four pounds)."

Spaeth [2] also, without being aware of the experiments just cited, adopted a similar method to investigate the state of the muscular sense in two cases of ataxy, and in both he found a notable diminution in the individual's discriminative power—indeed, in one of the two cases no difference was perceived unless the successive weights bore the ratio to one another of 1 to 100.

There can be no doubt that some of a patient's ability (3) to discriminate the extent of active or passive movements executed, as well as some of his knowledge of the position of his limbs, depends upon kinæsthetic impressions coming from the skin and from joints. Some have supposed that all this kind of knowledge comes from these ordinary kinæsthetic impressions.

Wundt, for instance, thinks that these sensations belong to a different category from those by which we appreciate weight or resistance.[3] Gley [4] also seems to think that the knowledge of the position and movements of the limb is derived in the main, if not wholly, from skin and joint impressions.

This, however, is in my opinion an erroneous conclusion, based upon the examination of one of the exceptional cases of hemianæsthesia, like that recorded by Demeaux (p. 11). A study of the two cases last quoted from Landry [5] shows conclu-

[1] Translation of Trousseau's 'Lectures,' 1866, p. 212.
[2] Beitr. zur Lehre von den Tabes Dorsalis. Tübingen, 1864.
[3] *Loc. cit.*, t. i., p. 426.
[4] Rev. philosoph., December, 1885, p. 605.
[5] Obs. iv. and v. (see pp. 23 and 24).

sively that knowledge as to the position and movements of the limbs may be more or less lost even when cutaneous sensibility is not at all or but little impaired. Other good clinical evidence may also be adduced pointing in the same direction. Thus Bazire, in reporting a case of locomotor ataxy, says[1] :—"His gait was very characteristic of locomotor ataxy. . . Within the last few weeks he had noticed that he could not tell the position of his limbs in bed, under the bed-clothes. He still complained of numbness of the legs, and yet, strangely enough, when tactile sensibility was tested with the æsthesiometer, it was found unimpaired, for he could feel the two points of the instrument at a distance of only two inches, when applied in front of the legs." In cases of this kind, it could only be expected that there would be a defective knowledge of the position of the limbs while the limbs are at rest, in bed. As soon as they are moved, when sensibility is either intact or but little impaired, the accompanying superficial sensations must necessarily give a pretty accurate knowledge as to their position. This source of difficulty is present, therefore, in all cases in which superficial insensibility does not exist though loss of the muscular sense is suspected; we cannot well move the limb or parts of the limb (such as the fingers) about at random, with the view of asking in what exact position they are ultimately left, without giving the patient *some* aid through his intact sense of touch. Of course if, in such a case, we still find that the patient has a defective appreciation of the position in which his limbs are ultimately left, the evidence is all the stronger that his "muscular sense" must be defective.

It thus seems clear that of the three disabilities above named, the second and third are dependent almost if not entirely upon loss of the muscular sense, whilst the first (the knowledge of the extent and direction of passive movements, and of the position of limbs) is very greatly due also to "muscular sense" impressions, though it is in part undoubtedly derived from other less special kinæsthetic impressions.

In regard to the very extraordinary cases recorded by Duchenne, Briquet, and Bazire, in which the third of the above-named disabilities was carried to such an extent that

[1] Trousseau's 'Lectures,' translated by Bazire, part i., case vi., p. 195.

even the simplest movements could not be performed at all without the aid of the sense of sight, it seems to me that we have here to do with functional defects in the cortical termini for "muscular sense" impressions, as well as interference with the functional integrity of the afferent channels for such impressions. These latter are alone affected (in concert with the afferent channels for other sense impressions) in those more ordinary severe cases of hemianæsthesia of that type recorded by Demaux. But in these altogether extraordinary cases of Duchenne and Briquet there existed, I think, in addition a low functional activity of the "muscular sense" centres[1]; that is to say, these centres could not be roused into activity by comparatively weak associational stimuli (as during volition with eyes closed); though they were able to respond under the influence of a stronger stimulus from the visual centre. May we not have in certain *hysterical paralyses of cerebral type* a still greater functional degradation of these "muscular sense" centres? Such patients do not move the affected limb or limbs either when their eyes are open or closed.

We may find illustrative, though not exactly parallel, conditions among speech defects of an amnesic type, due to a lowered functional condition of the auditory centre. When these, for instance, cannot be roused into proper activity by ordinary associational stimuli, the patient, as a consequence, cannot recall the words that he wishes; and, as a further consequence, cannot utter such words. This is a kind of paralysis, so far as these speech movements are concerned. On the other hand, such a patient may be able to repeat at once words uttered before him by another person. The affected auditory centre in this case reacts to the stronger stimulus; just as I imagine the affected "muscular sense" centres reacted in the cases of Duchenne, Briquet, and Bazire, under strong associational stimuli coming from the visual centres.

Supposing, however, the left auditory centre to be more damaged still, either functionally or structurally, speech becomes impossible. Speech is paralysed, in fact, in such a case, if the degradation of the auditory centre be of functional type, in just the same way as I suggest a hysterical patient is

[1] See 'Brain as an Organ of Mind,' pp. 616 and 621.

paralysed when she is suffering from a very low functional condition of her "muscular sense" centres for leg or arm, or both.

It is extremely interesting to find, in the case of Bazire, the complete inability to move the limb without the stimulus of sight impressions, existing only in the leg, while in the arm there was an approximation to this condition.

A fuller understanding of my views, in regard to these very interesting cases, may be expected after the reader has studied a subsequent section of this paper on the part taken by "Muscular Sense Impressions in the Execution of Voluntary and Automatic Movements" (p. 52).

Having said thus much concerning kinæsthetic impressions as a whole, and "muscular sense" impressions in particular, it may now be well to endeavour to show that both kinæsthetic impressions as a whole and these "muscular sense" impressions in particular, are, like other sensations, capable of being revived in idea. It seems desirable to advance something like a formal proof of this here, as, in our opinion, these ideal revivalsof kinæsthetic impressions aid in the performance of most important functions—that is, in the execution of all the voluntary movements we perform.

Just as the blind man can recall to mind previous sight impressions, or the deaf man sounds previously heard, so can the man who has had an arm amputated call to mind movements which this limb had formerly executed, by reviving in idea the kinæsthetic impressions previously associated therewith. Many remarkable instances of this have been recorded by Weir-Mitchell in his work entitled 'Injuries of Nerves and their Consequences' (p. 348, *et seq.*). I am inclined to think that in very many of these cases the conjuring up of subjective impressions of the several kinds mentioned is more facile than in persons who are neither blind, deaf, nor armless; and that, in many instances, the impressions so revived, assume such an intensity as to appear more like hallucinations than ordinary sensory revivals. Weir-Mitchell says:—"Nearly every man who loses a limb carries about with him a constant or inconstant phantom of the missing member, a sensory ghost of that much of himself. . . . The sensation of the presence of

the part removed exists in many persons as soon as they come from under the influence of the anæsthetic used at the time of the amputation, but in others it only arises after they cease to suffer pain, being rarely delayed beyond three weeks. The more healthy the stump, the less perfect after a time becomes the sense of the existence of the limb removed, while it is liable to be recalled by a blow or anything which causes a return of subjective sensation. . . . Even in those who are least conscious of the missing part, I have amazed them by suddenly recalling it with the aid of a faradic current applied to the nerves of the stump. It is not easy to forget the astonishment with which some of these persons re-awaken to a perception of the long lost leg or arm."

In regard to the ideal recall of movements of the missing member, Weir-Mitchell says:—"We find that in a very small number there is no consciousness of power to stir any part of the absent members by force of will. All others are able to will a movement and apparently to themselves to execute it more or less effectively, although in most of the amputated such phantom motions are confined to the fingers or toes, which rarely seem to possess the normal range either of flexion or extension. Yet the certainty with which these patients describe the limitations of motion, and their confidence as to the place assumed by the parts moved, are truly remarkable; while these restricted movements are pretty surely painful, and the effort is apt to excite twitching in the stump. . . . A small number have entire and painless freedom of motion as regards all parts of the hand. 'My hand is now open, or, it is shut,' they say. 'I touch the thumb with the little finger.' 'The hand is now in the writing position,' etc. Between these cases and such as are conscious of an immobile member, every grade of difference as to motion is to be found."

Another very remarkable fact of some importance is that, according to Weir-Mitchell, such sensations may be roused at will and even revived after they have been in abeyance for years, by stimulation of afferent nerves. He says:—"If we faradise the track of the nerve in or above the stump, we may cause the lost fingers and thumb to seem to be flexed and extended, and, what is most remarkable, parts of which the

man is conscious, but which he has not tried to stir for years, may thus be made to appear to move, to his utter amazement. In one case I thus acted on the nerves, so as to cause a thumb which for years was constantly and violently bent in on the palm to straighten out completely. On breaking the circuit without warning, the patient exclaimed that his thumb was cutting the palm again, and the same result was obtained by shifting the conductors so as to put the nerves out of the circuit. . . . In a case of amputation at the shoulder-joint, in which all consciousness of the limb had long since vanished, I suddenly faradised the brachial plexus, when the patient said at once, 'My hand is there again. It is bent all up and hurts me.' These impressions are correctly referred by the patient, so that faradisation of the musculo-spiral, or the ulnar, gives sensations of movement in the related parts."

These effects of faradisation of the nerve trunks are very interesting, and are entirely in accordance with the statements previously quoted to the effect, that the more healthy the stump the less perfect, after a time, becomes the sense of the existence of the limb that has been removed. If a mere blow upon the stump tends to recall such a sensation, how much more should a definite stimulus applied to the very nerves themselves. These facts simply mean, that the kinæsthetic centres in relation with a lost limb are apt to drop into a condition of functional inertia, but that they are easily roused from this state by the advent of afferent stimuli, and that they are all the more powerfully roused when the stimulus applied is in itself powerful. In these statements, however, we are a little taking for granted the correctness of a view as to the nature of these impressions which has not yet been formally considered (see p. 42), although some of the strongest evidence in its favour has already been adduced in preceding pages.

In regard to the varying power of recall of kinæsthetic impressions exhibited by different persons whose limbs have been amputated, this may be due, in part, to varying conditions of the stump as above indicated; and perhaps more especially to varying states of the nerve ends, and the extent to which they are invaded by processes of sclerosis. Beyond all such causes of difference, however, we may expect that

there would be naturally in different individuals, great variations in the power of recalling kinæsthetic impressions, just as an extreme variability is met with in different persons in regard to their power of recalling visual or auditory impressions, as F. Galton has so fully shown in the case of the former. A few instances of such variations will well illustrate this part of our subject.

Galton made a series of careful enquiries to ascertain to what extent different persons are endowed with the power of recalling, or seeing with the mind's eye, distinct images of objects in their natural grouping and colouring, taking as a trial-subject the person's own breakfast table as he or she sat down to it in the morning. The one hundred answers which he received disclosed an extraordinary range of variation in this respect among different individuals, as may be seen by the perusal of his interesting essay on 'Mental Imagery.'[1] One of those who had the highest power of recall answers:—"Thinking of the breakfast table this morning, all the objects in my mental picture are as bright as the actual scene." One of the worst answers:—"No individual objects, only a general idea of a very uncertain kind." While the person who possessed the lowest power of all in this direction, answered:—"My powers are zero. To my consciousness there is almost no association of memory with objective visual impressions. I recollect the breakfast table but do not see it." Other very interesting examples of variation in this power of recalling visual images are cited. Thus Mr. Galton says:—"One statesman has assured me that a certain hesitation in utterance which he has at times, is due to his being plagued by the image of his manuscript speech, with its original erasures and corrections. He cannot lay the ghost, and he puzzles in trying to decipher it. . . . A distinguished writer on metaphysical topics assures me that he is exceptionally quick at recognizing a face that he has seen before, but he cannot call up a mental image of any face with clearness. . . . There are a few persons in whom the visualising faculty is so low that they can mentally see neither numerals nor anything else; and again there are a few in whom it is so high as to give rise to hallucinations."

[1] 'Inquiries into Human Faculty,' 1883, p. 83.

With variations such as these to be met with in regard to the impressions of a vivid sense like that of sight, it is much more easy to explain, by the principle of individual variation, some of the remarkable differences in the power of recalling kinæsthetic impressions met with among the persons examined by Weir-Mitchell.

The cases to which we have just been referring are instances in which kinæsthetic impressions as a whole are revived. There is, however, good evidence to show that "muscular sense" impressions in particular are also capable of being revived in idea. It has been already shown that these are the impressions which almost, if not quite alone, are concerned with the estimation of weight or resistance. If such impressions, however, had not been capable of being revived in idea, we should have no power of discriminating differences in weights when they are lifted in succession, and still less should we have that power which we possess of lifting certain bodies and saying at once what is their approximate weight.

In the former case we have mentally to compare our present feelings of resistance with our memory of similar impressions experienced a few moments before; whereas, the fact of our possessing such powers as are referred to in the second case, shows, that we are capable of acquiring ingrained "standards of weight" by the constant exercise of this faculty, dependent of course upon our power of ideally recalling such impressions, so that at last we are enabled to judge intuitively as to the approximation of bodies to certain ideal standards of weight, just as we are enabled to judge of the approximation of certain presently perceived colours or sounds to certain "standard" visual or auditory impressions. In regard to this point Professor Bain says:[1]—"Absolute weight implies a permanent standard, and a permanent impression of that standard. When I lift a weight, and pronounce it to be seven pounds, I make a comparison between the present feeling and the impression acquired by handling the standard weight of seven pounds or things equivalent thereto. This absolute comparison, therefore, implies the enduring and recoverable sensibility to impressions of resistance, which is also a fact of the human

[1] 'The Senses and the Intellect,' 3rd ed., p. 93.

constitution. . . . A receiver of posted letters contracts an ingrained sensibility to half an ounce, and can say, of any letter put into his hand, whether it produces a sensibility equal to or under the standard."

But it is one of the fundamental positions of physiological psychology which Professor Bain has strongly enforced, that a renewed feeling or idea must depend upon the action of precisely the same parts as the original feeling. On this head he says[1]:—"What is the manner of occupation of the brain with a resuscitated feeling of resistance, a smell, or a sound? There is only one answer that seems admissible. The renewed feeling occupies the very same parts, and in the same manner as the original feeling, and in no other parts, nor in any other assignable manner. . . . For where should a past feeling be re-embodied if not in the same organs as the feeling when present? It is only in this way that its identity can be preserved; a feeling differently embodied would be a different feeling."

The Nature and Origin of "Muscular Sense" Impressions.

Almost all that has been written by others in regard to what I have in this paper spoken of as "kinæsthetic impressions," has been brought forward in relation with the several writers, views concerning the existence and nature of that power in us whereby we are enabled to judge of "resistance" or "weight." This power has been discussed by them under such different names as these:—"muscular sense" (Sir Charles Bell); a "sense of force" (E. H. Weber); a "sens de l'activité musculaire" (Landry); a "conscience musculaire" (Duchenne); a "locomotive faculty" (Sir William Hamilton); the "feelings of movement" (Bain); and the "sense of innervation" (Wundt).

Some of these writers, such as Sir William Hamilton[2] and Wundt,[3] have carefully discriminated the different components of the group of impressions accompanying and resulting from

[1] 'The Senses and the Intellect,' 3rd ed., p. 338.

[2] 'Notes and Dissertations on Reid.'

[3] 'Éléments de psychol. physiol.,' 2nd ed. (trad. franç.), 1886, t. i., pp. 421–426

movements; others, like Landry [1] and Bain [2] have not always been careful to make such discrimination, but have spoken rather as though all the impressions derived from movement might be included under that endowment which others speak of as the "muscular sense"—a laxity which is all the less likely to recur if the term kinæsthetic should be adopted as a general designation for the whole mixed group of impressions which accompany movement.[3]

From a psychological point of view the highest interest has attached to these discussions, seeing that the sensations of "resistance" which we derive through the exercise of our muscles have been supposed to give us a knowledge altogether apart from that derivable through so-called "passive sensations"—an immediate knowledge, in fact, of an external world or "non-ego."

Those who consider that through the performance of movements we acquire a kind of knowledge which is altogether peculiar, are not precisely agreed among themselves as to the exact mode in which they so acquire it. These, however, are altogether minor differences, and as a class the holders of such views must be separated from another group of psychologists and physiologists who maintain that there is nothing intrinsically peculiar in the sensations and impressions constituting that combination of feelings which comes to us as a consequence of movement.

Omitting minor detail, therefore, we have two points of view in reference to the nature and origin of the impressions whence we derive our knowledge of "resistance" and of

[1] 'Mém. sur la paral. du sentim. d. activ. musc.' 1855, p. 262.

[2] 'The Senses and the Intellect,' 3rd ed., p. 82.

[3] This looseness of phraseology is, in fact, still very common, as may be judged from the following quotation from Ferrier, where he is speaking of the views of Hitzig and Nothnagel. He says (*loc. cit.*, p. 379): "The term muscular sense, as ordinarily understood, and as employed by these authors, is applied to the assemblage of centripetal impressions generated by the act of muscular contraction in the muscles themselves, as well as in the skin, fasciæ, ligaments, and joints." Historical references bearing upon the subject of the "muscular sense" generally, are mainly to be found in the following three places, but especially in the last of them:—Hamilton's 'Notes and Dissert. on Reid'; Bastian's 'Brain as an Organ of Mind,' *Appendix*; and Sternberg, in Pflüger's 'Archiv f. Physiol.' Bd. xxxvii.

"weight," whereby we acquire our knowledge of the different degrees of "consistence" of bodies, and (through consciousness of the nature and extent of our movements) whereby we learn the differences in "form" which bodies present.

These conflicting views must now be briefly but definitely stated, in order that it may be made perfectly clear which of them is in accordance, and which at variance, with facts that are now well established:—

(1.) According to the first view our notions of "resistance" are not derived from sensations at all, but are due to a central psychic process (to which Wundt has applied the term "sense of innervation"). In reference to such a view Ludwig says:—"It is conceivable and not unlikely, that all knowledge and discrimination arrived at through the exertion of the voluntary muscles are attained directly through the act of voluntary excitation; so that the effort of the will is at once proceeded on as a means of judgment." On this subject also, J. Müller said:—"It is not certain that the idea of the force employed in muscular contraction depends solely upon a sensation. We have a very exact notion of the quantity of nerve-force starting from the brain which is necessary to produce a certain movement. . . . It would be very possible that the appreciation of the weight and pressure in cases where we raise or resist, should be in part at least not a sensation in the muscle, but a notion of the quantity of nerve-force which the brain is excited to call into action." According to Wundt, "the strength of the sensation is dependent only on the strength of the motive influence passing outwards from the centre, which sets on the innervation of the motor-nerves." Bain, again, holds "that the sensibility accompanying muscular movement coincides with the outgoing stream of motor-energy, and does not, as in the case of pure sensation, result from an influence passing inwards, by ingoing or sensory nerves," or, as he elsewhere says, "we are bound to presume that this is the concomitant of the outgoing current by which the muscles are stimulated to act." Hughlings-Jackson, amongst ourselves, has always been a strong upholder of these views.

(2.) The opposite view is not so old. The earliest statement that I have seen to the effect that the sensations accompanying

or resulting from movement are afferent and not efferent feelings, is that of Lotze, who says:[1]—"We must affirm universally that in the muscular feeling we are not sensible of the *force* on its way to produce an effect, but only of the *sufferance* already produced in our moveable organs, the muscles, after the force has, in a manner unobservable by us, exerted upon them its causality." This view was, however, very shortly after, much more clearly expressed by Landry[2] in these terms:—"The *ego* has a direct consciousness of the phenomena of volition; it knows immediately that there has been a voluntary stimulus, and to what part of the body it has been directed; as to the effects produced, it is only mediately informed of these, and can disregard them. . . . The nervous action which incites the movement can only, therefore, furnish to consciousness an idea of the volition, and not that of its execution; besides, if the sensorium has a knowledge of the excitation of the excito-motor faculties, it ignores the quantity of the nerve action exerted. It is necessary that the effect of the central incitation (the contraction) should be produced in order that the brain may perceive, and then it perceives at the same time both the seat and the degree of contraction. The movement is, therefore, the source whence we derive notions of this kind."

In 1869 I expressed the view,[3] that "*all* the information which Prof. Bain considers to have been revealed to us by the activity of our locomotive organs through an 'active' mode of sensibility, has been derived from modes of passive sensibility (occasioned, it is true, by this activity), and from inferences which have gradually been built up upon these . . . The feeling of 'expended energy,' therefore, by which we obtain our ideas of resistance and of an external world, is not contained, as we think, in the volitional act itself, but is derived from impressions emanating from the moving organs themselves during the actual accomplishment of movements." And after referring to the clinical evidence that was available

[1] 'Medicinische Psychologie,' 1852, p. 293.

[2] 'Traité des paralysies,' Paris, 1859. Similar views were indeed expressed in his memoir in the 'Gaz. des Hôpitaux,' 1855.

[3] "On the 'Muscular Sense,' and on the Physiology of Thinking." 'British Medical Journal,' April, 1869.

at that time, concerning cases in which the so-called "muscular sense" was supposed to be more or less defective, I arrived at the following conclusion :—"There is clearly a loss of something in these cases, of a something which serves as a guide in the execution of voluntary movements, but whose absence can be compensated by the supervision of the visual sense; and this is, in great part, the function which some physiologists attach to the 'muscular sense' . . . my position is that these impressions of the muscular sense, whose existence we are thus obliged to postulate, are *unconscious*[1] impressions, and that the conscious impressions that have usually been stated to fall within its province are really derivable through modes of ordinary cutaneous and deep sensibility."

In 1880, whilst adhering to almost precisely the same views, I maintained[2] that the time had come when it would be advantageous to speak, in lieu of a "muscular sense," of a "Sense of Movement, as a separate endowment, of a complex kind, whereby we are made acquainted with the position and movements of our limbs, whereby we judge of 'weight' and 'resistance,' and by means of which the brain also derives much unconscious guidance in the performance of movements generally, but especially in those of the automatic type. . . . There are included under it, as its several components, cutaneous impressions, impressions from muscles and other deep textures of the limbs (such as fasciæ, tendons, and articular surfaces), all of which yield conscious impressions of various degrees of definiteness; and in addition there seems to be a highly important set of 'unfelt' impressions, which guide the motor activity of the brain by automatically bringing it into relation with the different degrees of contraction of muscles that may be in a state of action."

Meanwhile Ferrier had also expressed a strong opinion adverse to the views of Wundt and Bain.[3] He said :—"But, whether we make the movements in reality, or revive them in idea, the consciousness of the extent and energy of the move-

[1] In regard to this point, see what I have said on p. 5 (Note [2]) of this paper.
[2] 'The Brain as an Organ of Mind,' pp. 540–544.
[3] 'Functions of the Brain,' 1st ed., 1876, p. 226.

ment is, in my opinion, in all cases dependent on in-going or centripetal impressions."

A few weeks after the publication of my work 'The Brain as an Organ of Mind,' there appeared a remarkable paper[1] by Dr. William James, of Harvard University, on 'The Feeling of Effort,' in which will be found many views strikingly similar to those that I have expressed. In reply to the question as to the nature of our sensible perceptions of movement he says:— "I unhesitatingly answer: an aggregate of afferent feelings, coming primarily from the contraction of muscles, the stretching of tendons, ligaments and skin, and the rubbing and pressing of joints; and secondarily, from the eye, the ear, the skin, nose or palate, any or all of which may be indirectly affected by the movement as it takes place in another part of the body. The only idea of a movement which we *can* possess is composed of images of these its afferent effects." Again he says:— "The *degree of strength* of our muscular contractions is completely revealed to us by afferent feelings coming from the muscles themselves and their insertions, from the vicinity of the joints, and from the general fixation of the larynx, chest, face and body, in the phenomena of effort, objectively considered. When a certain degree of energy of contraction rather than another is thought of by us, this complex aggregate of afferent feelings, forming the material of our thought, renders absolutely precise and distinctive our mental image of the exact strength of movement to be made, and the exact amount of resistance to be overcome."

Such language may seem very positive, but in my opinion also this second view as to the afferent nature of all the impressions by which we obtain a knowledge of our movements and by which we judge of weight and resistance is one that may now be considered to be incontestably established. Sachs[2] has shown the existence of sensory nerves in muscles, and such clinical evidence as is afforded by the cases of Demeaux, Landry, Spaeth, Duchenne, Briquet, and Bazire, show conclusively what opinion we ought to adopt in regard to this much disputed point. We have to do in these patients with

[1] 'Anniversary Memoirs of the Boston Society of Natural History,' 1880.
Reichert's u. Du Bois-Reymond's 'Archiv,' 1874.

a total disappearance, in the parts affected, of all that kind of knowledge which has, by one or other, been ascribed to, or supposed to be derived from, the "muscular sense." They were ignorant of the position of their limbs, unconscious of any movements that they might execute, and of the degree of resistance which might be opposed to the contraction of these muscles. The volitional centres, the spinal motor centres, the motor nerves and the muscles were capable of being called into activity—yet all the information usually supposed to be derived through the "muscular sense" had vanished. No clearer evidence could be forthcoming to show that the knowledge of the position of our limbs, of their movements, and of the state and degree of contraction of our muscles generally, does not depend as Wundt, Bain, and others assume, upon impressions that are "concomitants of," or that coincide with, "the outgoing stream of nervous energy."

I go even further, and maintain that the processes taking place in motor centres and in motor nerves are purely physiological processes, wholly devoid of any conscious accompaniment—that is to say, from the time the motor incitation leaves the kinæsthetic centres, up to the time when muscular contractions occur, we have only to do with a series of physical processes occurring in different motor centres and in motor nerves.

Writing on this subject in 1880 I said[1]:—"The kinæsthetic centre is indeed one of great importance. Its impressions enter inextricably into a large number of our mental processes —as widely and inextricably, in fact, as the assumed muscular consciousness of Bain is supposed by him and others to be intertwined with what they would distinguish as passive sensibilities. But it can only produce an extreme amount of confusion if the activity of this sensory centre is attributed to and confounded with that of motor centres, the processes of which seem to lie even more truly outside the sphere of mind than the molecular processes comprised in the actual contraction of a muscle: these latter processes are, at least, immediately followed by 'ingoing' impressions, whilst so far as we know—that is, so far as any evidence exists—the former are

[1] 'The Brain as an Organ of Mind,' p. 600.

not." After so much as we are conscious of in the mere volition itself, "we have to do with molecular currents passing, it may be, through several sets of fibres and cells, but having no conscious side whatever." [1] Again, "Motor centres, wherever they may be situated, are parts whose activity appears to be wholly free from subjective concomitants. No ideal reproductions appear ever to take place in such centres; they are roused into activity by outgoing currents, and so far as we have any evidence, the induction in them of molecular currents which immediately afterwards issue through cranial and spinal motor nerves to muscles are simply physical phenomena." [2]

Views almost exactly similar to these were published only a few weeks later by Wm. James, in his essay on 'The Feeling of Effort.' Thus, he says (p. 20):—"In a word, volition is a psychic or moral fact pure and simple, and is absolutely completed when the *intention* or *consent* is there. The supervention of motion upon its completion is a supernumerary phenomenon belonging to the department of physiology exclusively, and depending on the organic structure and condition of executive ganglia, whose functioning is quite unconscious." Or again (p. 4):—"But apart from *à priori* postulates, and however strange to logic it may appear, it is a fact, that the motor apparatus is absolutely insentient in an afferent direction, although we know that the fibres of the anterior root will propagate a disturbance in that direction as well as in the other. Why may not this result from a true insentiency in the motor cell? an insentiency which would accompany all action there, and characterize its normal discharges as well as the unnatural irritations made by the knife of the surgeon or the electrodes of the physiologist upon the motor nerves." Again (p. 7)—"One immediate conclusion follows: namely, that there are no such things as afferent feelings, or feelings of innervation. These are wholly mythological entities. Whoever says that in raising his arm he is ignorant of how many muscles he contracts, in what order of sequence and in what degrees of intensity, expressly avows a colossal amount of unconsciousness of the processes of motor discharge."

[1] *Loc. cit.* p. 495. [2] *Loc. cit.* p. 599, see also p. 149.

I am happy to be able to cite another distinguished convert to these views. If any one will compare what was said by Prof. Ferrier in the first edition of his 'Functions of the Brain'[1] with what he says in the following passages taken from his recently-issued second edition (p. 436) it will be seen that he has made a most important renunciation, and now holds doctrines entirely in accordance with those above expressed. The views he now holds are these:—"The activity of the motor centres has no subjective side apart from the functioning of the sensory centres with which they are associated . . . whereas we have sensory ideation in and by itself, we have no ideas of movement apart from the sensory centres through which alone the activity of the motor centres is revealed in consciousness."

Many important issues in regard to cerebral localisation, as well as concerning psychological doctrine, turn upon the correct interpretation of the questions which we have just been considering.

In regard to the former, with which we are here chiefly concerned, it may be well to point out in the first place, that the interpretation of aphasia, aphemia, and all the varied amnesic states must differ widely from one another according to the different views which are taken as to the nature and seat of so-called "motor-ideas." The very notion of such a thing as a "motor-idea" could only arise in the mind of a man who believed we had feelings which could be felt, and

[1] At p. 266, he said:—"In the same manner as the sensory centres form the organic basis of the memory of sensory impressions, and the seat of their representation or revival in idea, so the motor centres of the hemispheres, besides being the centres of differentiated movements are also the organic basis of the memory of the corresponding movements, and the seat of their re-execution or ideal reproduction. We have thus a sensory memory and a motor memory, sensory ideas and motor ideas; sensory ideas being revived sensations, motor ideas being revived or ideal movements." Again at p. 271, he said:—"If the motor centres of the cerebral hemispheres are not merely the centres of impulse of volitional movements, but also the centres of registration and revivability of the same, it must follow that destruction of the cortical motor centres will cause not only objective motor paralysis, but subjective motor paralysis, or, in other words, paralysis of motor ideation." These views which Ferrier has, I am glad to say, renounced are thoroughly in accordance with doctrines still held by Hughlings-Jackson, and Stricker.

consequently ideas that could be revived, in motor centres. It so happens also that those who hold this doctrine have always been inclined to believe (though it does not of necessity follow), that such revived "motor ideas" constitute the material of our recollection when words recur to the mind in silent thought; this, for instance, has been the doctrine of Bain, Wundt, Hughlings-Jackson, and more recently of Stricker. Those, however, who répudiate the notion of the existence of any such things as "motor ideas," and who believe that all our ideas of movement are revived in sensory centres, have also for the most part supposed, that words are primarily revived in silent thought in the auditory centres, and that the kinæsthetic ideas of words are awakened in immediate succession thereto.

These divergent views lead to widely different interpretations of the various species of speech defects, and such interpretations entail quite different views as to the localisation of the lesions by which they are severally caused. This any one may see who will take the trouble to compare Stricker's account of such defects, as embodied in his work[1] 'Du langage et de la musique,' with that which I have advanced in a recently published work.[2] The different interpretations we have offered of so-called "word-blindness" and "word-deafness" might be looked to as an example of what I mean. The whole question is, however, far too large a one to be entered upon here.

Again, if our sensations of movement were "concomitants of the outgoing current," and if we really had "motor ideas" as well as sensory ideas, it would be perfectly natural and logical to look for motor centres in the cerebral cortex; but if these views are erroneous, and if all our knowledge of movements comes to us through sensory centres, then there is no longer the least ground for postulating the existence of motor centres in the cortex; all that would be needed there would be the existence of sensory registers of the impressions occasioned by movement. In other words, kinæsthetic centres clearly must exist in the cerebral cortex, to be as it were on the same platform with the registers for other sensory impressions with

[1] Paris (Biblioth. de philosoph. contemp.), 1885.

[2] 'Paralyses: Cerebral, Bulbar, and Spinal,' 1886, pp. 99–130.

which they are in such intimate functional relationship; whilst the actual need for the existence of motor centres in this situation has not yet been shown by any one.

The Part taken by "Muscular Sense" Impressions in the Execution of Voluntary and Automatic Movements.

(*a*) *Voluntary Movements.*

In voluntary acts we have not merely to account for the production of a movement, but of a movement of a certain kind, in which the action of each set of muscles brought into play is duly regulated so as to lead to the exact result desired. And, seeing that the volition or desire to bring about such and such movements originates in the cerebral cortex, so we are bound to admit, that the purely volitional qualities of the movement must also depend upon cerebral influence. Hence the strength, the continuance, the rapidity, and the direction of movements are variable according to the precise nature of the cerebral incitation or volition. As Jaccoud says, "The strength of the movement is regulated by the strength of the initial motor impulse; the extent depends in reality upon the same influence; the rapidity results from the more or less rapid succession of voluntary impulses; and the direction is determined by the voluntary localisation of the incitation upon certain groups of muscles." It is also important to recollect that, in the execution of a complex movement, any alteration that we may desire to bring about in respect of any one of these volitional qualities, is, by the mere change in the volition itself, immediately effected with reference to the movement as a complex whole. Jaccoud illustrates this as follows[1]:—"I am walking, and then I wish to walk more quickly. Hardly have I conceived the desire before the mode of walking is changed; it has become in short, more rapid. This intervention of my will manifests itself, therefore, by a change in the movement of locomotion as a whole. This change is the final result of a series of partial modifications which have been brought about in the original movement; this is incontestable. But I have

[1] 'Les paraplégies et l'ataxie du mouvement,' 1864, p. 594.

not needed a parallel series of volitional acts; a single volition has sufficed. I have willed to walk more quickly, and I have then walked more quickly, without knowing anything, without even requiring to know anything, of these intermediate modifications." In the same way, alterations in any one of the other volitional qualities of a complex movement are found to have direct bearings upon the movement as a whole. These seem to be the principal facts that should be mentioned with regard to the mere volitional act; and I am quite disposed to agree with Landry when he says, in opposition to the views of several physiologists previously mentioned, that the volition itself includes only an incitation to a specific kind of movement, and that we must execute this movement in order to become acquainted (inferentially) with the quantity of nervous action brought into play.

But besides these *qualities* of the movement which are determined by the volition, we have to consider the execution of the movement itself as a compound of several simple movements, brought about by the simultaneous and successive contractions of different muscles, which are perfectly harmonious and constant in their mode of action. This machine-like precision of action—the result of what is usually known by the name of *co-ordination*—is now admitted by most physiologists to depend upon certain pre-established, though gradually acquired, nerve-connections between the different elements of the spinal cord and medulla oblongata. The movements are machine-like, inasmuch as they depend upon certain organic combinations in the spinal cord and medulla, and after these connections have once been fully formed the will has little more to do with them; the movements ordinarily take place in a definite manner, the will qualifying their mode of execution only. It requires a special exercise of mental power in order to execute certain complex movements in a way different from that which has become habitual. But in these cases, as well as when we are learning to execute a new complex movement, we give no attention whatever to the muscles by which the movement is effected—the states of these individually do not fall within the scope of our consciousness. Were it otherwise, the number and situations of the several muscles would reveal

themselves to all, during the performance of different movements. In our tentative efforts we think only of the movements themselves—how to combine the more simple, so as to produce the more complex.

The kind of movement produced is, therefore, evidently dependent upon the *distribution*, in the medulla and spinal cord, of the volitional impulse; and, in a complicated motor act, its incidence upon particular groups of cells, which are the organic representatives of certain potentialities for simple movements, gives rise to the production of the complex movement. The more frequently such a complex movement has been executed, the more completely may we suppose these various groups of cells become bound together into one system by connecting fibres, and the more possible is it for the movement which they represent to occur in a thoroughly automatic manner, and often without much need for cerebral intervention. The mechanism of co-ordination is, therefore, purely spinal. This fact was fully recognised by Volkmann more than forty years ago, as appears from the following quotation:[1] "The physiological accomplishment of movements has nothing to do either with consciousness or with unconsciousness, for the mind has not the least notion of the details of this operation; and even in voluntary movements it knows nothing concerning the nerves or the muscles by the intervention of which the process is accomplished. In fact, the mind does nothing in this case but give the incitation; and if this incitation has for an effect any co-ordinated movement, it is altogether simply because the organ which receives the incitation is arranged in such a fashion that it necessarily produces a co-ordinated movement." Precisely the same views as these were also expressed, at about the same time, by Arnold and Müller.

Thus, the work of co-ordination tends to become entirely spinal and organic; the movement itself depends upon the spinal cord, though its particular *qualities* of force, rapidity, etc., are dependent upon the cerebral or volitional influence. The cerebrum may, therefore, also be said to exercise a kind of co-ordination—it co-ordinates or adapts the movements which are

[1] Art. 'Nervenphysiologie,' in Wagner's 'Handwörterbuch,' 1844.

organically represented in the spinal cord, so as to make them accord qualitatively with the aim conceived. But, in order that the cerebrum may exercise this power, it seems perfectly obvious that it should be instructed from moment to moment as to the exact nature of the movement actually produced, so that it may know whether to continue in its present mode of action, or whether to vary the quality of the volition, in order better to attain the desired end. Now, according to Jaccoud, whose treatment of this subject is most excellent, the cerebrum obtains these necessary guiding impressions from different sources. He says: "These indispensable notions the brain obtains directly through the sense of sight; or, instead it deduces them indirectly from the instructions which reach it as to the situation of the parts which move and the condition of the contractile organs which move them; these instructions are furnished by impressions through the muscular sense, and through the sense of touch." The sense of sight is what we chiefly rely upon in early years, and in acquiring new movements generally. We all know how long it is before a person learning to play upon a musical instrument can do without the aid of this guiding sense. At last, however, his tactile sense, and also his "muscular sense," has become so educated that he is able to do without guidance from the sense of sight; and, as a rule, he does without this primary aid as soon as the execution of the movement has become perfectly easy. Jaccoud calls the second mode of appreciation indirect, because it does not, as in the case of the sense of sight, depend upon a simple perception of transmitted sensations, but upon an interpretation of sensations. As he says[1]—"The sensorium requires, as a preliminary, to have learned the relations which unite the various conditions of the muscles, or of the tactile organs to the different sensations perceived; it is only at the termination of this apprenticeship that it can conclude from the sensation perceived as to the statical or dynamical conditions of the parts whence the sensation springs. This education proceeds correctly, by means of the direct appreciation through the sense of sight, thanks to which the individual can compare at each instant the movement effected with the sensation perceived."

[1] *Loc. cit.* p. 601.

After this preliminary education has been finished, the knowledge so acquired, though inferential, becomes as available and as efficacious as that which is more directly derived through the sense of sight. It can be brought into action also with just as much rapidity and exactness, so that the sense of sight is no longer needed to inform us as to the position of our limbs, and as to the nature and degree of their movements.

Jaccoud, therefore, thinks that the power which healthy persons enjoy of performing, with facility, movements that are at the same time habitual and complex depends, in the first place, upon the integrity of their "muscular sense," and in the second, upon that of their sense of touch. Impressions are derived through both these channels, whereby the brain becomes informed as to the amount and kind of movement which it has called into action; and so it learns whether, to obtain the end in view, it should continue with the same kind of volition, or whether it should be qualified in any way.

When we commence a movement, we initiate it with certain predetermined qualities of force and extent; and this, of course, is simply a result of our past experience and education. I know that certain objects have hitherto given me certain impressions of weight when I have previously handled them, and therefore my previous education now enables me, when I see such an object again and desire to handle it, to give the volitional act its necessary qualifications. This power has been termed "*l'instinct locomoteur*," and "*conscience musculaire*." It has been made the subject of much mystification, though it is a simple result of our capability of recalling in idea the kinæsthetic impressions which have previously been associated with given sight impressions; that is, the sight impressions immediately recall their related kinæsthetic impressions. When I see a simple bundle of wool on a table, as a result of previous experience I can at once nearly accurately determine what ought to be the quality of the volition necessary to enable me to raise it. Thus I am enabled to initiate such a movement as I deem appropriate. But supposing, in the case just cited, that the supposed simple bundle of wool was not a simple bundle, that it contained a heavy leaden weight in its centre, then my initial volition would have been inadequate, I should have

been deceived, and the kinæsthetic impressions that I received would have instructed me that a stronger volitional effort was necessary. It is always in this way that kinæsthetic impressions are supposed to intervene.

By a supposed "locomotive instinct" (or, in other words, ideal recall of kinæsthetic impressions), we know, as Jaccoud puts it, *what force we ought to employ*, whilst by the actual occurrence of kinæsthetic impressions we are taught *what force we have employed.*

I have now for some time advocated such views as these, and have maintained that the immediate execution of voluntary acts, in the case of the majority of limb-movements, is dependent upon the guidance of co-active visual and kinæsthetic centres; just as in the case of the complex movements concerned in articulate speech, the immediate execution of such movements is dependent upon the regulative activity of combined auditory and kinæsthetic centres.[1] The latter movements seem, in short, to be related to the auditory centres, in just the same sort of way that movements of the limbs are related to the visual centres.

Where the movements which it is desired to execute are complex and difficult and we have to learn them by imitation of the movements of other persons, the sense of sight is doubly brought into action. It is necessary at the commencement and during the continuance of our efforts to copy such movements, to look alternately at our model and at our own moving members. A long time and much practice is, in fact, required before a person who is learning to play upon some musical instrument, is able to execute the necessary actions without the aid, from moment to moment, of guiding visual impressions. During the process of learning, therefore, the visual centre evidently exercises a dominating influence.

In time, however, the impressions pertaining to the "sense of movement" (which are, of course, always associated with those of sight) become, by way of newly organized channels, sufficiently well associated with the newly organizing motor mechanisms, to permit the new movement whenever it has been initiated to be continued under the immediate guidance

[1] 'Brit. Med. Journal,' April, 1869, and 'The Brain as an Organ of Mind,' p. 555, and chap. xxix.

of kinæsthetic impressions only—that is, without further necessity for a conjoint direction through the sense of sight.

The same different tracts of the brain that are called into simultaneous or immediately successive activity for the initiation of any set of voluntary movements, would probably remain in activity during the continuance of such movement, though not exactly in the same relative proportions. Thus, if we suppose the centres specially called into activity, as guiding centres, to be the visual and kinæsthetic, it may well be that the former has a dominating influence in the production of the initial conception of the movement about to be executed. And yet the distinctness of this idea or conception of the movement (partly visual and partly kinæsthetic in its origin, as we have said) will be found to vary with the degree of familiarity, and consequently with the ease of execution, of the movement. In the case of the simplest voluntary movements, or those that have been often repeated, an idea or conception of the movement needed scarcely obtrudes itself at all as a conscious element of the volition. This is a part of the process which has here become more or less latent, and which in ideo-motor and sensori-motor actions has become wholly latent; though it probably still remains, even in these latter, as a necessary link in the chain of causation. On the other hand, during the continuance of voluntary as well as of almost all varieties of automatic movements, it seems clear that the kinæsthetic centres exercise the supreme guiding influence. Its impressions alone—even when they very imperfectly, or not at all, rouse our consciousness as to their existence—suffice to inform us (that is, suffice to excite their proper cerebral "centres" in ways definitely related to different positions and muscular tensions) as to the exact relations of our limbs, and as to the nature and degree of their movements.

The mode of acquisition above indicated, seems well to accord with our other interests and with the daily necessities of our lives. The sense of sight greatly facilitates the process of learning, and its vivid impressions speedily enable the brain to appreciate aright the more vague and occult impressions coming to it simultaneously through the kinæsthetic centres. Soon, however, the visual sense, which we need for so many

other important purposes, no longer requires to be concentrated wholly on the performance of movements. Later still, our attention or consciousness becomes further freed from disturbing details connected with movements. The possibly conscious impressions pertaining to the "sense of movement" at last habitually pass unheeded, and then we come to be able to perform multitudes of daily actions under the guidance of mere "unconscious" kinæsthetic impressions.

Thus the working of the motor side of our complex nervous mechanism, even when it is concerned in executing the behests of will, proceeds so smoothly, and is practically so much unheeded, as to leave us free to follow up the threads of our conscious life unhindered by the multitudinous details pertaining to the varying states of innumerable muscles acting in ever changing combinations.

Thus from what has been said it seems clear that the performance of a voluntary act is always preceded by an idea or conception of the movement we desire to execute; and that this idea or conception is, for ordinary movements, compounded of two kinds of past impressions, namely, those of the visual sense and those of the kinæsthetic sense. Again, it must be remembered that the kinæsthetic sense includes two different sets of impressions; the one set (*a*) being conscious impressions derived from our moving members (proceeding from skin, muscles, tendons, and joints); the other being (*b*) either unfelt, or almost completely unfelt, impressions emanating from the muscles, in relation with their varying states of contraction, and therefore affording information to the brain of the most important kind. The evidence demonstrating the existence of this last set of comparatively unfelt impressions emanating from muscles, and pointing to their importance for the guidance of movements, is mainly derived from cases of diseases such as have been already cited (pp. 10–20).

Now, in the chapter on "The Will," in his "Analysis of the Human Mind," published more than fifty years ago, it appears that James Mill clearly appreciated the fact, that the "idea of the action" to be performed is two-fold. He says, "There are two ideas very different from one another, to both

of which we give the name 'idea of the action.'" Of these, he adds, "one is the outward appearance of the action, and is always a very obvious idea." The other is a copy of certain internal sensations, which a few pages before he had spoken of generally as sensations accompanying the movement, and which he also more specifically defined (*loc. cit.* p. 275) when speaking of the terminal events of a movement as "the contraction of the muscles, with the various sensations which the action upon those organs, and the action excited in them, imply." Of these internal sensations he says, "from the habit of not attending to them, we have lost the power of attending." And then he adds, "This last (namely the revival of such internal sensations) is by no means an obvious idea. And the mind passes from it so quickly, intent upon the action which is its result, that it is almost always swallowed up in the mass of association. It constitutes, in fact, one of the most remarkable instances of that class of links in a chain, which, how important soever to the existence of the chain, are passed over so rapidly, that the existence of them is hardly ever recognized. . . . *This last idea alone is that upon which the contraction is consequent.*"

This view is then essentially that which I myself adopt, viz., that kinæsthetic impressions, and especially those of which we are least conscious, are the last to be revived in the cerebral cortex, anterior to, and as actual last links in the chain of cerebral processes which determine, the excitation of the motor centres themselves.

I find that since the first publication of these views, very similar notions as to the importance of revived sensations of movement for the execution of voluntary acts have been expressed by two other writers.

The views of one of these, namely Dr. E. Fournié, were published three years afterwards;[1] and though we do not at all agree in our general interpretation of perceptive processes, nor as to the regions of the brain concerned therewith, we are thoroughly in accord as to the importance of these sensations of movement in conjunction with other sensory impressions as guides for movements generally. Thus, he fully

[1] 'Physiolog. du syst. nerveux,' 1872, pp. 291, 360, 362-5, 447

recognized the important part played by revived sensations of muscular contraction in voluntary as well as in instinctive movements; also the difficulty of reviving such impressions alone, when they have not been linked with visual or auditory impressions. It is true, he does not seem clear as to the mode in which such revived sensations of movement come into play, though he firmly believes that conjoined sensory impressions are the true cerebral co-ordinators of movement, and that by the aid of these alone we are enabled to learn new movements. He holds that sensations telling of the state of contraction of the muscles are "indispensable conditions in order that each movement may be directed in a suitable fashion," and says that, but for our power of recalling in idea or reviving such impressions, new movements could never be perfectly learned, so that the "execution of movements would be an eternal apprenticeship."

But much more important and more generally in accordance with my own views are the statements made by Dr. W. James. He says[1]:—"The essentials of a voluntary movement are—(1) a preliminary idea of the end we wish to obtain; (2) a '*fiat*'; (3) an appropriate muscular contraction; (4) the end felt as actually accomplished. In man at any rate it is admitted that the idea of the end and the muscular contraction were originally coupled by empirical association; that is to say, the child with his end in view, made random movements till he accidentally found one to fit. This movement awakened its own characteristic feeling which thenceforward remained with him as the idea of the movement appropriate to that particular end.[2] If the man should acquire a million distinct ends, he must acquire a million such motor ideas and a million connections between them and the ends. But one such connection, subserved by an exclusive nerve tract used for no other purpose, will be enough for each end. The end conceived, will, when these associations are formed, always

[1] *Loc. cit.*, 1880, p. 5.

[2] In a note further on, Dr. James calls attention to an important point. He writes (*loc. cit.*, p. 9):—"I may add that in teaching a new and unnatural movement, the starting-point is to awaken by its passive production a distinct sense of what the movement, if effected, would feel like. This defines the direction of the exertion the pupil is to make."

awaken its own proper motor idea. As for the manner in which this idea awakens its own proper movement—the one which will convert it from an idea into an actual sensation—the simplest possible arrangement would be to let it serve directly (through its peculiar neural process) as a stimulus to the special motor centre, the ultimate sensible effect of whose discharge it prefigures and represents." Again, he says:—"If I will to write 'Peter' rather than Paul, it is the thought of certain digital sensations, of certain alphabetic sounds, of certain appearances on the paper, and of no others, which immediately precedes the motion of my pen. If I will to utter the word 'Paul' rather than Peter, it is the thought of my voice falling on my ear, and of certain muscular feelings in tongue, lips, and larynx, which guide the utterance. All these feelings are afferent, and between the thought of them, by which the act is mentally specified with all possible completeness, and the act itself, there is no room for any third order of mental phenomena. Except indeed what I have called the fiat, the element of consent, or resolve that the act shall ensue. This, doubtless, to the reader's mind, as to my own, constitutes the essence of the voluntariness of the act."[1]

But the so-called "fiat" has no particular mystery about it. It is the mere result of the fact, that one out of the two or more motives which weigh themselves against one another, is, after little or much deliberation, recognised to be stronger than the others; the result being that the molecular movements with which it is associated are permitted to flow over into motor channels so as to evoke the fitting muscular actions. As James says:—"In our bed we think of the cold, and we feel the warmth and lie still, but we all the time feel that we can

[1] In regard to the nature of this "fiat" we may say, with James Mill, that it is simply equivalent to a *desire* sufficiently strong to be immediately operative (see 'The Brain as an Organ of Mind,' p. 550). Hartley said also, "The Will is, therefore, that desire or aversion which is strongest for the present time." Which mental mood is to prevail is sometimes immediately settled, and at other times only after a process of Deliberation. Concerning this process Hobbes said:—"The whole sum of desires, aversions, hopes and fears, continued till the thing be either done or thought impossible, is what we call *Deliberation*. . . . Appetite, therefore, and aversion are simply so called as long as they follow not deliberation. But if deliberation have gone before, then the last act of it, if it be appetite, is called *will*; if aversion, *unwillingness*."

get up *if we will.* The difficulty is to will." In the case of emotional actions, the mere presence of the exciting idea is much more apt immediately to excite the corresponding movement, so that "the discharge of idea into movement is much more readily inhibited by other casually present ideas in the case of voluntary action, and less so in the case of emotions; though here too inhibition takes place on a large scale." As a result of these considerations he lays down the following important conclusion,[1] "*that every representation of a motion awakens the actual motion which is its object, unless inhibited by some antagonistic representation simultaneously present to the mind.*"

W. James very neatly summarizes his own as well as my views on this part of the question, when he says:—"The ordinary 'voluntary' act results in this way: First, some movement produces a feeling in a reflex, or as we say, accidental way. The movement excites a sensorial tract, causing a feeling which, whenever the sensorial tract functions again, revives as an idea. Now the sensorial and motor tracts, thus associated in their actions, remain associated for ever afterwards; and as the motor originally aroused the sensory, so the sensory may now arouse the motor (provided no outlying ideational tracts in connection with it prevent it from so doing). Voluntary acts are, in fact, nothing but acts whose motor centres are so constituted that they can be roused by these sensorial centres, whose excitement was originally their effect."

Finally, it would seem clearly to follow, from the views above set forth, that in all essential respects the cerebral mechanisms for the actual production of voluntary, of ideo-motor, and of emotional movements are identical—that is to say, that the "way out" from the sensory centres in which the idea of the movement to be effected is revived, and the efferent tracts thence onwards towards the motor centres by which the movement is to be actually evoked are, when the movement itself is similar, identically the same in each of these cases.

The sensory components of the idea of the action about to be performed are, moreover, always twofold. They either belong to the visual and the kinæsthetic orders, or else they are auditory and kinæsthetic, as in the case where speech movements are to be evoked. The cases are rare in which, with ordinary seeing

[1] *Loc. cit.* p. 17.

individuals, we have the combination in idea of special tactile with kinæsthetic impressions. In the blind, however, this particular combination for the ideal recall of movements becomes very common.

In each case the "conception of the movement" about to be executed, being a means rather than an end, does not after a time attract our attention. If this is so even with the initial guides of movement (that is, the revived visual and auditory impressions), how much more may we expect it to be the case with the revived kinæsthetic impressions, which are always less vivid. And how little even the initial guides of movement, when revived in idea, at all clearly reveal themselves to consciousness in many persons is evidenced by the fact, that it is denied by Prof. Stricker and some other persons that words are primarily revived, anterior to articulation, in the auditory centres.

It is, however, neither customary nor needful either for thought or for action, that the several links in the chain of association by which these processes are effected should reveal themselves in consciousness. Many of the links of our thought and of our sensorial action are represented by sub-conscious nerve processes, and this is clearly the case with regard to those linked revivals of sensory activity which immediately precede and guide muscular movements. Transitions from conscious to unconscious nerve actions are habitually taking place during the education of the individual and the development of the nervous system in each one of us; and yet the essential nerve actions either still go on in the latter case, and none the less surely exercise their influence, in evoking other nerve actions which are associated with conscious states, or in leading to the production of this or that form of movement.

(*b*) *Automatic Movements.*

As we have seen, between voluntary and ideo-motor or emotional acts no really intrinsic differences exist, from the point of view of the nerve centres concerned with their production.[1]

[1] In the first edition of his 'Functions of the Brain,' Dr. Ferrier distinctly argued as though the nerve mechanisms needful for the production of voluntary

Are we to hold, however, with Ferrier and others, that there are special motor centres for the performance of voluntary actions altogether apart from those by the aid of which automatic actions are performed? This is a view to which I cannot subscribe. An automatic movement is simply what was once a voluntary movement in the race from which the individual has sprung. The motor mechanisms that are now immediately concerned with its execution are precisely those which were originally linked together or "organized" when such a movement first began to be effected by voluntary efforts.

The difference here, as I contend, is not with the motor centres; it lies rather with the nervous processes which precede the action of the motor centres. Thus, when eating, one swallows food by a series of automatic actions, without taking heed of the process; but I can at any time, by directing my attention thereto, and with the presence of saliva as an additional stimulus, voluntarily perform these same processes. In the one case the movements are evoked as mere reflex actions in which the medulla is the centre concerned; in the other they are evoked under the influence of volitional stimuli whose birth and starting-point is to be found in the cerebral cortex.

It is, therefore, in my opinion, a fundamental error to look for special motor centres for the production of voluntary movements of any kind—either in the cortex or elsewhere.

The cerebral hemispheres are needed for the learning of new movements which in succeeding generations of animals come to be performed in a purely automatic manner; or, we ourselves may learn movements which ultimately by dint of time and long practice may become so facile that they take their place in the category of "secondary-automatic" actions. These facts seem to me to show conclusively that, in the learning of any new movement, two processes of education (entailing the establishment of structural connections, or the laying down of new nerve routes) must take place concurrently.

movements were different from those by which ideo-motor and emotional movements are evoked. In the recently issued second edition he does not so explicitly state this view (*loc. cit.*, p. 371), nor does he clearly retract it.

One must be carried on in the cerebral cortex in the way already described; whilst another must be effected by developmental processes taking place in lower centres, of the action of which we are altogether unconscious—processes which, with lapse of time and successive generations, ultimately permit such movements to occur in a purely automatic fashion, and, it may be, without any concurrent stimulus either reaching or rousing the activity of the cerebral cortex.

It has now been perfectly well established, by experiments on lower animals, that even such complex muscular actions as are required for station and locomotion may be performed in pigeons and in rabbits after the cerebral hemispheres have been removed. Here, therefore, it is clear we have only to do with a series of very complex reflex actions, carried on by means of the mesencephalic and cerebellar centres. It is true that afferent impressions of various kinds are needed for the effective performance of the very complex muscular actions required for the maintenance of equilibrium and for locomotion—there must, in fact, be the advent of proper visual impressions, of labyrinthine impressions, of tactile impressions, and above all of "muscular sense" impressions. With the sole presence of these, however, the necessary movements for locomotion may be evoked, even though in its natural condition the animal is also in the habit of constantly inciting these same complex movements by volitional stimuli. The motor centres in action remain the same, they are merely called into play in a different manner; and in each case the actual movement, whether reflex or volitional, is evoked by stimuli starting from sensory centres.

For the execution of many other automatic movements the kinæsthetic impressions which impinge upon lower centres are of less importance than tactile impressions; these latter, in many cases, are the special stimuli which evoke the acts, whilst kinæsthetic impressions here also serve as absolutely unconscious guides—especially where the act is one which involves a succession of muscular movements. It must be upon the basis of information coming to the spinal cord itself in the form of kinæsthetic impressions, that, even in animals in which the cerebral hemispheres have been removed, as Goltz has shown,

we may at times observe new adaptive movements called forth of a distinctly purposive type, that is, with a view to remove some unusual stimulus. This is an adaptive power which, as Dr. Ferrier admits,[1] the evidence compels us to concede to the spinal cord.

This kind of use to which kinæsthetic impressions are put in the case of automatic movements, holds good for movements of different degrees of complexity, and equally so whether they are evoked under the guidance of mesencephalic, of medullary, or of spinal sensory nuclei.

But by the time a new movement has been thoroughly learned by any particular race of animals, that is, after its constant repetition by successive generations of such animals, these tactile and kinæsthetic impressions to lower centres (whether they be spinal, medullary or mesencephalic) having been habitually impinging upon such centres (as well as making their way to the cerebral cortex) must have opened up direct channels of communication between such lower sensory centres and the related motor mechanisms, so that the corresponding movements are then capable of being evoked in a purely reflex fashion, after the manner of automatic movements generally—that is, on the mere occurrence of the suitable stimulus, and without necessity for the intervention of the cerebral hemispheres. It is true that, in the majority of cases, the cortical connections with such motor centres still exist, so that the same movement may, whenever the desire is felt, continue to be evoked by a voluntary stimulus. This, as we have seen, is the condition of things with regard to the movements of deglutition already referred to, as well as for station and locomotion in many of the lower animals.

Experiments upon lower animals seem, indeed, to teach us that if we take different creatures such as frogs, rabbits, dogs,

[1] 'Functions of the Brain,' 2nd ed., p. 118, where he says:—"By a series of ingeniously contrived experiments Goltz has shown that, even when the limbs of a frog were so fixed or placed in positions which could not have occurred in its past experience, the animal, without its hemispheres, retained the power of adapting its movements in accordance with these unusual and abnormal conditions. This would indicate that, if these centres are merely centres of reflex action, the reaction is that of a machine possessing in some way the power of self-adjustment."

or monkeys, we find in the first mentioned a comparatively small number of movements that are not purely automatic, and consequently a very small number of these which are permanently interfered with by a removal of their cerebral hemispheres. In rabbits and dogs, however, we find movements more and more interfered with after removal of the cerebral hemispheres, showing, according to my interpretation of the facts, that a larger proportion of the movements of these animals are as yet unemancipated from the necessity of cerebral control and guidance in the manner I have indicated through sensory centres. In monkeys, again, we meet with a large increase in the proportion of movements which are still so comparatively new (for the race), as to be only capable of being evoked by stimuli emanating from the cerebral cortex. While in man, the knowledge we have acquired from the study of disease, as well as our knowledge of the infinitely diversified uses to which the human hand may minister, suffices to convince us that the influence of the cerebral cortex in the production of movements even very greatly surpasses that which obtains with the monkey.

Thus, we find in man the kinæsthetic centres, as well as the visual, auditory, and tactile centres, alike obtaining their maximum development, because of the extremely diversified uses and the complexity of the processes to which they are called upon to minister. The very fact of the greater development of all these sensory centres in man, and of the enormous number of the movements which are suggested and guided by his intelligence, probably tends to maintain movements generally in him more, and for a longer time, under the influence and guidance of the cerebral cortex, than similar movements would be in lower animals. Hence the larger amount of motor defect produced in man by certain cortical lesions, simply because these lesions destroy those sensory centres in the cortex from which the volitional stimuli or controlling incitations immediately issue.

This is a kind of explanation which seems to me much more harmonious with all the facts than that advanced by Dr. Ferrier and others, which supposes that there are motor centres for voluntary movements altogether distinct from those for auto-

matic movements, and that these imaginary "motor centres for voluntary movements" are situated in the cerebral cortex.

The Cortical Localisation of "Muscular Sense" Impressions.

We have seen that there are practically three groups of cases in which loss or defect of "muscular sense" impressions is apt to be met with (p. 21) :—(*a*) cases where there is disease in the posterior columns or posterior cornua of the spinal cord ; (*b*) cases of cerebral hemianæsthesia, in which there is functional or structural disease in the region of the posterior extremity of the internal capsule ; and (*c*) cases which I previously spoke of as a more ill-defined group, but which I will now venture to say are cases of disease in the so-called motor regions of the cerebral cortex.

In regard to the precise path through the spinal cord taken by muscular sense impressions, nothing definite can as yet be said, beyond what has been above indicated. It is principally with some forms of locomotor ataxy, among spinal diseases, that defects of "muscular sense" are met with, therefore we suppose these impressions must pass upwards either through some part of the posterior column or else through the posterior cornua of the cord.

We are also unable definitely to trace the path pursued by "muscular sense" impressions through the medulla, pons, and cerebral peduncle. The fact, however, that in a very large proportion of cases of cerebral hemianæsthesia no loss of the muscular sense exists while, in other rare cases, these special impressions as well as any others that may be derived from muscles are entirely absent, tends to make it probable that in or near the posterior part of the internal capsule the channels for these impressions are gathered together in a more or less distinct fasciculus, before they diverge on their way to the cerebral cortex.

The final question that now presents itself for consideration, however, is :—What are the parts of the cortex to which these "muscular sense" impressions proceed ? Can this be said to be known, or not ?

In seeking to obtain an answer to this question, we ought to look for certain evidence that may be obtainable from experiments upon lower animals, and we should supplement this information by other evidence of a clinico-pathological nature derived from the effects of disease of the cerebral cortex in man, or from the effects resulting from removal of portions of the cortex on account of disease in this situation.

Evidence obtainable from lower animals.

What information may we fairly seek to obtain on this subject from experimentation upon the lower animals, and especially upon monkeys? From what has been said as to the functions of the "muscular sense" centres in the cortex in reference to movements generally, it seems obvious that they must be divided into two classes, from the point of view of the degree of their relationship to the activity of the cerebral cortex. Thus we have:—

Class I.—Voluntary actions in the largest sense of that term, among which we would include all those movements of varying degrees of facility (that is ranging from new difficult movements, to those of ideo-motor type) which cannot be executed apart from cortical instigation and guidance, proceeding from the opposite cerebral hemisphere.

Class II.—Actions that are only at times incited voluntarily (that is, by incitations from the cerebral cortex), but which are, in the great majority of cases, evoked by the reflex activity of lower centres as true automatic movements.

It is necessary to bear this distinction in mind because, as will be seen, the results of destruction of the "muscular sense" centres in the cerebral cortex on the one hand, and of their stimulation on the other, should be different for the two classes of movement.

Supposing, for the sake of our argument, we have *destroyed* the whole of the "muscular sense" centres of one hemisphere (the centres through which, in all actions that are performed voluntarily, the motor centres of the opposite side of the pons,

medulla, and cord, receive their ultimate guiding stimuli), the following result ought to ensue :—

	Classes of Movement.	Results.
Destruction of "Muscular Sense" Centres in One Hemisphere.	Movements of Class I. . .	All of them paralysed.
	Movements of Class II. . .	These movements not paralysed.

With practice under such conditions, and after some time, it is probable that some of the movements of Class I. which were nearest akin to those of Class II. would become capable of re-execution. They would pass indeed from the one class into the other—so that some amount of recovery from paralysis might be brought about in this way.

Now let us, in the same way, consider the effect of *stimulation* either of all or of some of the "muscular sense" centres in one hemisphere, and ascertain the effects that should be induced in regard to the same two classes of movement :—

	Classes of Movement.	Results.
Stimulation of "Muscular Sense" Centres in One Hemisphere.	Movements of Class I. . .	Contractions or spasms affecting the muscles by which these movements are performed.
	Movements of Class II. . .	Do. do.

Evidence obtainable from observations on Man.

From destruction or stimulation of the "muscular sense" centres in man, we may look for just the same kind of effects, in reference to the two classes of movement, as we have above said might be expected to occur in the lower animals. There should be a difference in degree only, dependent upon the fact of the far larger proportion of movements which, in man, belong to Class I., as compared with Class II. As a matter of fact (thanks in great part to the experimental investigations of Dr. Ferrier), we are now all familiar with the paralyses that result from destructive lesions in the Rolandic area of the cortex, and with the various forms of "Jacksonian Epilepsy" resulting from irritative disease in these same regions.

Other defects, however, may be looked for in the case of man, over and above those of which we can obtain distinct evidence from animals, as a result of destruction of his

"muscular sense" centres. These are certain defects of sensibility of such a kind that it would be quite hopeless to attempt to obtain any clear and reliable evidence concerning them by experiments upon, and observation of, any of the lower animals.

It is all the more necessary to insist upon this point, because some experimenters have drawn conclusions from their observations as though it were possible to obtain such evidence from the lower animals. But, I would ask, how is it possible for us to form any trustworthy judgment concerning a blindfolded animal's knowledge (1) of the extent of the active or passive movements of one of its limbs, or of the exact position in which it may be left at the termination of these active or passive movements; or how, again, (2) are we to judge whether the animal's ability to discriminate differences in weight or resistance with one of its limbs has suffered any diminution? These are much the most valuable means of testing the integrity of the "muscular sense," yet no evidence can be obtained in regard to either of them which is of the least value, except from an animal that has the power of speaking and telling us what his impressions are under the various trial circumstances. The only other kind of test (of less value than the two above-named, because it leads to more equivocal results) is (3) the testing of the animal's ability to perform certain definite movements with one of its limbs when its eyes are closed. How difficult it must be to obtain any reliable information upon such a subject by observations upon a blindfolded animal can be easily imagined, if we look only to the limited range of movements of a suitable kind which the animal could be induced to perform under such conditions. This, however, is not the whole extent of the difficulty that we should have to face in such an investigation; there is the further complication, that the animal's limb which it would be most important to test in regard to the integrity of its "muscular sense" impressions, in the particular experiments with which we are concerned, would be partially paralysed, and thus all attempts to test the integrity of its muscular sense impressions by this third and only means which is available in animals would be rendered still more fallacious and untrustworthy.

I am strongly of opinion, therefore, that all the statements which have been made in reference to the integrity or otherwise of special "muscular sense" impressions, in any of the lower animals that have been operated upon, are altogether valueless,[1] and that we must look only to observations upon man to throw any true light upon this side of the question.

The additional defects which ought to be met with in man, however, as a result of disease of the "muscular sense" centres are of this kind. Destructive disease, or removal by the surgeon, of parts of the "muscular sense" centres should lead, in proportion to the completeness of the destruction of the parts, to a more or less marked loss of that kind of knowledge which comes from the "muscular sense" in connection with the parts of the limb that are paralysed, or the whole limb or limbs, as the case may be. In a patient in whom ordinary tactile sensibility is not much affected, if we find, after various random passive movements with eyes closed, that he cannot tell correctly the position in which his limb or fingers may be left, the evidence becomes all the stronger that there must be a notable defect in the "muscular sense," because, as may be supposed, in such a case the patient may derive some guidance towards such knowledge through skin impressions. In these cases, therefore, the loss of the "muscular sense" would *always seem to be less than it really is*, and unless great care be taken it would be easy for a superficial observer to come to the conclusion, that it was not impaired at all. One precaution, for instance, should always be taken. That is, the observer, after passively moving the patient's limb or fingers, must be careful not to let his own fingers remain in contact with the patient at the end of these passive movements, when he asks as to the position in which the limb or fingers may have been left. If, however, we should have our suspicions that part of a patient's ability to tell the nature of passive movements made, or of the position in which his limb is left, comes from the guidance that he derives through the tactile sense, we must resort to other methods before we arrive at a positive opinion as to whether the "muscular sense" is defective or not.

[1] See note to p. 9.

In doubtful cases, therefore, perhaps the most trustworthy means of arriving at a positive conclusion as to the integrity or otherwise of this sense are these three (neither of which would be applicable, be it observed, in the case of one of the lower animals):—(*a*) Ascertaining whether the patient has or has not a complete knowledge of the position of the limb or limbs in question on first awaking from sleep, and before they are moved in any way; (*b*) Testing his ability to appreciate differences in weight with the part affected[1]; and finally (*c*) we may resort to a method adopted by Westphal and also by Horsley (a method which is particularly useful when the part to be tested is much paralysed), that is, ascertaining when the patient's eyes are closed with what readiness, or the reverse, he may be able to bring the forefinger of the sound hand at once upon any particular part that may be indicated to him (though not touched) of the affected limb in a state of rest. With a defective knowledge of the presence and position of a limb, the power of at once finding a particular part indicated would probably be distinctly impaired.

In brief, then, it comes to this, that if we have regard to the functions of the "muscular sense" department of the kinæsthetic centres (of which they form the nucleus or most essential part), we should expect that their stimulation would lead to spasms and convulsive movements of the parts whose motions are in relation therewith; that destruction of such centres would, on the other hand, lead to a paralysis of those movements which have hitherto only been evoked by the action of these centres; and, further, that in this latter case, there would also be a loss or marked diminution of "muscular sense" in the parts principally affected.

It will at once be seen that these are precisely the effects which have now been ascertained to follow upon the stimulation and destruction of the so-called "motor centres" in the cerebral cortex, the position of which, thanks to the successive labours of Fritsch and Hitzig, of Ferrier, of Carville and Duret, of Exner, of Horsley and Schäfer, and of Beevor and Horsley, have now been very thoroughly ascertained. The

[1] With specially charged gun cartridge cases after Galton's method, or some other equally delicate means. (See 'Inquiries into Human Faculty,' 1883, p. 370.)

position of the centres in connection with different movements of the limbs and trunk have now, in short, been definitely localised by these various workers as well as by clinical observers, in different parts of the Rolandic area and of the marginal convolution.

My opinion, therefore, is that the evidence in our possession points very strongly to the conclusion, that Ferrier's so-called "motor centres" are in reality kinæsthetic centres in which "muscular sense" impressions in particular have been registered. The following reasons lead me to this conclusion:—

1.—All the effects resulting from the stimulation or destruction of these centres are, as I have already shown, in accordance with this view.

2.—This being so, the view that "motor centres" exist in the cerebral cortex cannot be correct, unless it can be shown that there is in the cortex of each hemisphere another totally distinct set of centres, the stimulation of which evokes definite movements, and the destruction of which involves an inability to execute the same movements. But, both experimental physiology and clinical medicine speak strongly to the fact, that there is but one set of areas (Rolandic and marginal) in which irritation or destruction leads to any such results. I claim, therefore, that these areas must be in great part (whatever other functions they may discharge) devoted to the registration of kinæsthetic impressions of the "muscular sense" order, which, as I have endeavoured to show, are so all-important for the production of voluntary movements.

3.—No valid reasons have ever been brought forward against this view. To this it may be replied that Dr. Ferrier has carefully examined such doctrines, in the last edition of his 'Functions of the Brain' (pp. 379–381), and that he has there shown how much such views are at variance with existing knowledge.

The necessities of the case compel me, therefore, to be frank concerning Dr. Ferrier's position in regard to, and his treatment of, this question, to which I have given considerable attention.

According to Hitzig[1] the so-called motor centres are the

[1] Reichert's u. Dubois-Reymond's 'Archiv,' 1870 and 1874; also 'Untersuch. in das Gehirn,' p. 59, 1872.

centres for the "muscular sense" or "muscle-consciousness," while according to Nothnagel,[1] though not the centres for, these regions are traversed by, impressions of this order. Both, however, adopt that lax view of the "muscular sense" which would make it include impressions from joints, skin, etc., or, in other words, all the impressions resulting from movement, which I have grouped together as kinæsthetic impressions. Thus their views, although nominally the same as mine, are really different, seeing that I am content to subscribe to the views of Ferrier as well as of Horsley and Schäfer, to the effect that the falciform lobe (hippocampus, gyrus hippocampus, and gyrus fornicatus) is the main seat, at all events, in which tactile impressions and those of common sensibility are registered. The convolutions in the excitable Rolandic area together with the marginal convolution, are, however, according to my view, the seats in which "muscular sense" impressions proper (the all-important constituents of kinæsthetic impressions) are registered, and from which volitional stimuli immediately issue. Arguments, therefore, which may be valid against the views of Nothnagel and Hitzig, in regard to the non-impairment of common sensibility in cases of destructive disease of the parts in question, may be of no avail against my doctrine.

As, however, we have much in common, it may be well to scrutinise Dr. Ferrier's attitude with regard to these views as a whole, especially as he does not endeavour to make any nice or essential distinctions between them.

Thus, he does not attempt to distinguish between the effects that might be expected to follow from loss of the "muscular sense" centres, and those which would result merely from the cutting off of the proper impressions from such centres, they themselves being left intact. Any one who has read the present paper will realize that from my point of view this is a most important distinction. In his first edition Ferrier pointed out that Nothnagel regards the cortical centres in question as "in some manner directly connected with the paths" of muscular sense impressions, while Hitzig regards them as the cortical termini for these impressions. In his second edition, he does not think

[1] Virchow's 'Archiv,' Bd. lvii. 1873.

it worth while to state any such distinction; he assimilates Nothnagel's doctrine to that of Hitzig, and, strange to say, assumes that the effect of the destruction of such centres would be ataxy rather than paralysis. He even repeats this as against my doctrine, saying, "It might explain ataxy, but not paralysis." This, as well as other remarks which he makes, convinces me that Dr. Ferrier has given no adequate consideration to the subject. Let me say definitely that, in accordance with my views, paralysis should result from the destruction of these centres; and that inaccurate and more or less disordered movements when the eyes are closed (ataxy) should be the effect of the cutting across of the paths of muscular sense impressions whether near the hinder part of the internal capsule or in the spinal cord.[1]

Ferrier, treating the question from the point of view of the mere cutting off of muscular sense impressions (which is in fact Nothnagel's doctrine, though not Hitzig's which he is ostensibly criticising), supposes, therefore, that the resulting defects would be of an ataxic order more especially, and then goes on to say that this is, at all events, not the nature of the defect met with in the monkey or in man. Then comes the following very positive statement:—"It is also certain—and a subject of daily clinical demonstration—that in paralysis from cortical disease the patient though unable to move his arm voluntarily, is perfectly aware of every movement passively communicated to it, and can state with exactitude whether his arm is flexed or extended, whether his fist is closed or open, and whether his finger is being flexed or extended gently or with force. His muscular sense, as well as every other form of common sensibility, is absolutely unimpaired." How very far this is from being an accurate statement, however, any one may judge

[1] In relation with this statement, it may be well here to recall the fact, that if a low condition of functional activity in the "muscular sense" centres should co-exist with a disease which cuts off its proper impressions from such centres, there may, in addition, be inability to perform the simplest movements when the eyes are closed (pp. 16–20 and 36); while, in other cases, with a still lower state of functional activity of the "muscular sense" centres (with or without co-existing hemianæsthesia), we should have to do with paralysis of a *hysterical type*, in which voluntary movements cannot be performed either with eyes closed or with eyes open (p. 36).

who will refer to the cases which I have previously cited (pp. 24–32), viz. the case of P. Zenner, presumably one of cortical injury, as well as the two cases recorded by V. Horsley, in which he had excised portions of the cortex. Afterwards, in his attempts to dispose of the doctrines of Hitzig and Nothnagel, Dr. Ferrier makes a series of statements which, to say the least, are, as I have attempted to show in previous parts of this paper, very insufficiently founded upon fact and actually misleading in their nature.[1]

In short, it seems to me perfectly obvious that Dr. Ferrier has never thoroughly thought out this portion of his subject, and that his expressed opinions have been, and still are, most inconsistent. He began, in the first edition of his justly celebrated work, by assuming that motor centres were seats in which the ideal recall of movements occurred[2]—though at the same time, and in flagrant opposition therewith, he strongly contended that all sensations resulting from movement reach the brain through afferent channels.[3] In the second edition of his work he has corrected this discrepancy. He now admits that the ideal recall of movements can only occur in sensory centres—though he appears to do all he can to explain away the importance of these kinæsthetic centres. He shows no gleam of recognition of their importance for the execution of voluntary movements.[4] He, indeed, expressly repudiates their influence in this direction (and the opinions of those who support such a notion) principally by means of two assertions which are almost wholly at variance with clinical teaching. Thus, he makes the extraordinary statement, that loss of tactile sensibility carries with it loss of the muscular sense;[5] and, further, that loss of the muscular sense never occurs alone, or, as he implies, otherwise than in direct proportion to loss of tactile sensibility.[6]

Dr. Ferrier's statements concerning the order of events in voluntary acts are, moreover, extremely inexplicit; his assumption that the mechanisms for such acts are organised in

[1] I mean the statements which I have quoted in Notes to pp. 15 and 23.
[2] See (*loc. cit.*) the first paragraphs of § 92, § 96, and § 98.
[3] *Loc. cit.* pp. 218–228.
[4] *Loc. cit.*, 2nd ed., pp. 432–438.
[5] See note on p. 22 of this paper.
[6] See note on p. 23 of this paper.

special cortical centres, rests on just as unsatisfactory a basis as does his notion, that all kinæsthetic impressions are mixed inextricably with tactile impressions in one and the same cortical terminus.[1] As this, in fact, is a rival hypothesis, I ought to quote it in Dr. Ferrier's own words, more especially as it is all, so far as I have been able to find, that he says throughout his work and on his own account concerning the cortical localisation of "muscular sense" impressions. After remarking that he considers it established "beyond all doubt that the falciform lobe is the centre of common and tactile sensibility," he adds[2]:—"In the same regions are also the centres of cutaneo-mucous and so-called muscular sensibility. . . . All the facts receive the most satisfactory explanation, if we regard the falciform lobe as a whole, and in each and every part the centre of tactile sensation for the whole of the opposite side of the body; though probably the various motor centres are each anatomically related by associating fibres with corresponding regions of the falciform lobe. This association would form the basis of a musculo-sensory localisation."

In the few remarks which Dr. Ferrier has made in regard to my views in particular,[3] he principally confines himself to a statement of the difficulties which he experienced in comprehending their precise meaning. These difficulties I trust he will now no longer experience; at least I have striven to explain my meaning as clearly as possible. Several of his statements concerning these views are not altogether correct, but one which he makes is extremely misleading, in more ways than one, and calls for some notice from me. He leads his readers to believe, that my views should not find favour because they are based upon an old and erroneous notion, that "the cortical centres act only through the corpora striata." How far this is from being a correct representation of my position the reader may judge for himself, seeing that this is the first occasion on which any mention of these basal ganglia has been made in this paper. My views are, in fact, wholly independent

[1] This latter conclusion is based upon deductions made from his observations upon animals. See note on p. 9 of this paper.

[2] *Loc. cit.*, 2nd ed., p. 344.

[3] *Loc. cit.*, p. 331

of any fixed notions concerning the functions of the corpora striata, as to which so much doubt has arisen of late years.[1]

Facts which favour or oppose the Notion, that the Centres in the Rolandic and Marginal Areas are real Motor Centres.

Having adduced the reasons which induce me to believe, that the so-called "motor centres" of the cortex are in reality the cortical termini of muscular sense impressions, and having discussed, and I hope shown, the futility of some of the objections which have been made to this view, I will now briefly glance (*a*) at the facts upon which reliance is placed by others in support of the notion, that these centres are really motor, and then turn (*b*) to an enumeration of the strong reasons which, in my opinion, can be brought forward against any such hypothesis.

(*a*) The first facts to be considered are the results of stimulation or destruction of the regions in question.

In regard to these it will be well, first of all, to quote what Prof. Ferrier says. He writes as follows:[2]—"As regards the physiological significance of these regions, we have seen that we cannot conclude, from the mere occurrence of movement on the electrical stimulation, that the regions are truly motor; for the stimulation of a sensory centre may give rise to reflex or associated movements. . . . Whether the centres now under consideration are directly motor, or only give rise to movements in a similar reflex, or indirect

[1] This criticism comes, however, all the more strangely from Dr. Ferrier, seeing that in my work 'The Brain as an Organ of Mind,' 1880, I certainly could not have said anything more definite about the functions of the corpora striata than he said in the first edition of his 'Functions of the Brain,' 1876, where I find the following statements:—"The cortical motor centres which necessarily act downwards through the corpus striatum" (p. 210); "The corpus striatum is the centre in which movements primarily dependent on volition proper tend to become organised" (p. 214); "In these cases, and in the dog deprived of its cortical centres, the path from impression to action is not, as in the ordinary course of volition, through the cortical motor centres to the corpus striatum, and thence downwards," etc. (p. 215). These were the statements concerning the corpus striatum which were backed by Dr. Ferrier's authority till about two months ago, when the second edition of his work appeared.

[2] *Loc. cit.*, 2nd ed., p. 347.

manner when stimulated, is a question which has been answered differently by different physiologists. The definite purposive character clearly perceivable in most of the movements, however, their correspondence with the ordinary volitional activities and individual peculiarities of the animals, and above all their uniformity and predicableness, harmonize best with the hypothesis, that they are the signs of the artificial excitation of the functional activity of centres immediately concerned in effecting volitional movements, *and as such truly motor.* If these centres are part of the mechanism of volitional movements, then paralysis of voluntary motion, *and of motion only,* ought to result from their destruction, and any apparent exception must be capable of satisfactory explanation in accordance with this view, if it is the correct one." This is in my opinion a thoroughly just statement in all respects, except in regard to the two passages which I have caused to be printed in italics.

To the first passage so printed I altogether demur, as being a complete *non sequitur.* The movements excited might also be expected to have all the characters described by Dr. Ferrier, if they were sensory centres "immediately concerned in effecting volitional movements," viz., those in which "muscular sense" impressions are registered. It is, in fact, a rule which obtains throughout the nervous system, that all motor centres whatsoever are always stimulated into activity through incitations coming from sensory centres or nuclei, consequently the electrical stimulation of such centres or groups of cells, or of the fibres issuing from them, should always evoke just such movements as the excitation of these centres or cells is accustomed to produce. Similarly, destruction of such centres or nuclei should render impossible all such movements as had previously been evoked by their agency as necessary factors.

Secondly, if "these centres are part of the mechanism of volitional movements," and if they subserve such functions as I have imagined, the second passage which has been underlined would also be altogether wrong; their destruction, in that case, would involve not only paralysis of voluntary motion but also loss of the so-called "muscular sense" in the related parts.

So far, then, there is nothing which may not be explained by my hypothesis with just as much ease as by the more fashionable notion. We come, however, now to another set of facts, which are pointed to triumphantly by Ferrier and his adherents, as a crowning proof of the truth of their notions, viz. to the fact, that the study of descending degenerations in the pyramidal tract conclusively shows, that efferent fibres pass continuously from the centres in the Rolandic and marginal areas downwards to motor centres in the medulla and throughout the whole length of the spinal cord.

To this I reply, that the direction of secondary degenerations affords good evidence as to the efferent or afferent functions of the nerve fibres which are so affected, and that our present knowledge shows conclusively that the fibres in the pyramidal tract are efferent fibres—a notion which I hold equally with Dr. Ferrier. This, however, does not at all touch the question, whether the ganglion cells which exercise a trophic influence upon such efferent fibres form constituent parts of sensory or of motor centres, which is the real question in dispute. If this trophic influence is a mere collateral incident of the functional activity of the cell, as is now generally supposed,[1] then it must always be exercised in the direction taken by currents starting from the cell, so that the fact, that secondary degenerations in the pyramidal tract pursue a descending course, merely tells us that we have to do with efferent nerves, and absolutely nothing as to whether the trophic cells from which they issue belong to sensory or to motor centres.

The direction of the degeneration says nothing, therefore, which is more in favour of Ferrier's than of my hypothesis.

Again, the fact that these pyramidal fibres pass directly downwards from the centres in question in the cerebral cortex to groups of motor cells situated in the pons, the medulla, and throughout the spinal cord, is a point which tells no more in favour of the one hypothesis than of the other.

Thus, it is an essential part of my general view (which I stated so long ago as 1869) to suppose, that the elementary motor mechanisms which are called into play in voluntary

[1] And as Dr. Ferrier himself imagines (*loc. cit.*, 2nd edit., p. 85).

movements are the same, and no other, than those which have to be called into action in corresponding automatic movements (see p. 65). This view has lately been strengthened by some valuable experimental researches of Ferrier and Yeo, concerning which the former says[1]:—"The stimulation of each motor root of the nerve plexuses of the limbs in monkeys, calls forth combined movements involving the co-operation of numerous muscles, widely separated from each other anatomically, but all resulting in actions such as are seen to be constantly associated together in the ordinary modes of activity of the animal." After giving illustrations of this, Ferrier adds:—"These facts render it probable that each segment of the cervical and lumbar enlargement of the spinal cord, whence nerves proceed to the limbs, is a centre of co-ordinated synergic muscular movements, of a character adapted to the habits and requirements of the animal in its ordinary modes of activity." Ferrier's recent work, therefore, gives a positive basis of support to the view which I had previously enunciated, and have lately reiterated,[2] though it seems to me to tell rather against his notion that there are separate motor centres in the cortex, on the ground that the spinal mechanisms merely require excitations from the cerebral cortex in order to evoke purposive movements.

Either view as to the functions of the cortical centres would still, and equally, leave in doubt the question, whether or not other centres in any way co-operated with these and the medullary or spinal centres in the bringing about of new and complex voluntary acts. Of course we know that, where station and locomotion are concerned, the cerebral incitation must be in part devoted to a rousing of activity in the conjoined mesencephalic and cerebellar centres. Again, supposing the thalamus and corpus striatum to constitute a higher couple still for the performance of acts which are not voluntary, as Dr. Ferrier suggests, we may ask what are the efferent fibres through which these centres act upon those below, and we may put the same question in regard to the combined mesencephalic and cerebellar centres. Such questions become all the more

[1] *Loc. cit.*, p. 76.

[2] 'The Brain as an Organ of Mind,' 1880, p. 558.

pertinent if applied to the case of a dog which has had its so-called "motor centres" removed from both hemispheres, and which, if it should live long enough, as in Carville and Duret's experiments, would presumably have secondary degenerations throughout both pyramidal tracks. Yet in such animals, after a time, both station and locomotion become possible.[1] Here, therefore, the incitation of all the motor nuclei needful for the accomplishment of the complex muscular contractions occurring during locomotion must take place through channels other than those pertaining to the degenerated pyramidal tracts. I make these latter remarks merely for the purpose of indicating how much we still have to learn upon this whole set of questions, and not with the view of showing that such difficulties press more heavily upon the one than upon the other of the two hypotheses now being weighed in the balance.

The above-mentioned are the only real grounds that have ever been put forward in support of the notion, that the centres in question in the Rolandic and marginal areas of the cortex are true "motor centres."[2] What has been said above, however, clearly shows that the facts admit of a totally different interpretation. If we put aside for the moment the question, whether the "muscular sense" is or is not impaired or lost in limbs, less or more paralysed from lesions occurring in these portions of the cerebral cortex, all the remaining facts are, to say the least, fully as much in accordance with my view as with that of Dr. Ferrier. If, however, subsequent observations on man should confirm what the observations of Horsley and Zenner render possible or even probable, that loss or impairment of the "muscular sense" will be found to exist in the paralysed parts in cases of cortical disease, then the balance of evidence would be completely turned in favour of my hypothesis, that these Rolandic and marginal centres are the cortical termini for "muscular sense" impressions. This would be crucial evidence which could not be gainsaid even by the

[1] Ferrier, *loc. cit.*, p. 367.

[2] The mere large size and other peculiarities of the nerve cells in these regions of the cortex may be explained by the one as well as by the other hypothesis, if we look to the nature of the stimuli issuing from them, and to the length of the paths which such stimuli would have to traverse.

most sceptical, since as Dr. Ferrier himself puts it, in accordance with his view that the above-mentioned cortical centres are true motor centres, "paralysis of voluntary motion, and *of motion only*, ought to result from their destruction."

(*b*) So far, however, I have only been discussing the value of the evidence which its supporters put forward in favour of their notion, that the cortical centres above indicated are true motor centres; it still remains for me to state, what can and ought to be said against the notion of the existence of any such centres in the cerebral cortex. Whilst, in fact, the additional evidence from observations on man, alluded to above, may be needed to convince the strongest partizans of the "motor" hypothesis as to the truth of my particular view, I trust many persons may be found to agree with me that, even in our present state of knowledge, the following considerations are amply sufficient to show, not only that there is now no independent foundation for the hypothesis that "motor centres for voluntary action" exist in the cerebral cortex, but that such a hypothesis is in reality repugnant alike to physiological and to psychological data.

The theory which first led to the postulation of the existence of such centres by Dr. Hughlings-Jackson has been thoroughly disproved, and nobody admits this more fully than does Dr. Ferrier himself. Hughlings-Jackson has always strongly supported the view of Bain as to our feelings of movement being "concomitants of the outgoing current," and that such feelings are ideally revivable in motor rather than in sensory centres. The logical corollary of these views is, undoubtedly, that motor centres should exist in the cerebral cortex. As we have seen, Dr. Ferrier has, one by one, dropt these fundamental doctrines as erroneous, and yet he still clings to a theory which is the natural associate of such rejected doctrines. His position is a very inconsistent one.

The supposition that motor centres exist in the cortex for the performance of voluntary movements, is, however, thoroughly repugnant in itself to what we may term the physiologico-psychological analysis of the volitional act. This teaches us that sensory centres are the real guides of volitional action; that their activity corresponds with the very essence of volition;

that they, in fact, do just such work as that which those who do not adequately think out the problems involved attribute to cortical motor centres.

Ferrier's view is equally repugnant to the physiology of movements from an evolutional standpoint, which teaches us that the self-same motor mechanisms which are at first called into play volitionally (that is, by incitations from cortical sensory centres), become, with lapse of time in new generations of animals, the motor mechanisms for corresponding automatic acts. Ferrier's view, that the centres in the cortex are motor, expressly says that they are for the accomplishment of volitional acts only; and at the same time he tells us nothing as to how this assumed registration of voluntary movements, in regions altogether distinct from those in which automatic movements are registered, can be reconciled with the fact, that every sort of transition exists between voluntary and automatic movements, and that many of the self-same movements are at times executed volitionally, though at other times they are performed as typical automatic movements. If he does not mean to say that the voluntary acts are registered in the cortical centres as actual motor mechanisms, then I maintain that, in consequence of an imperfect analysis of the phenomena of volition, he is simply attributing to assumed motor centres that guiding action which is really carried on in sensory cortical centres.

Finally, there is only one complete set of excitable areas in the cortex of each hemisphere (through which movements may be evoked in all parts of the body), but if Dr. Ferrier's views were true there ought to be two complete sets of such excitable centres in each hemisphere. Clearly and indubitably the sensory incitations to movement, constituting (as all admit) part of the volitional act, *must pass off from certain cortical areas in a definite and orderly manner in order to excite motor centres, wherever they may be situated.* I assume that they pass off in such fashion from the cortical termini for "muscular sense" impressions. The stimulation of these centres or efferent fibres, which must exist, should, therefore, clearly be capable of evoking purposive volitional movements. All those who, contrary alike to the teachings of psychology and of

physiology, would look for separate volitional motor centres in the cerebral cortex must seek to discover therein another distinct set of excitable areas. Perhaps it might be easier and more conducive to sound doctrine for them to reconsider the whole question?

It may be supposed by some to be, after all, a matter of no importance, whether we call these areas in the Rolandic and marginal regions of the cerebral cortex "motor centres" or not, especially seeing that, as I myself admit, they are the areas whence volitional motor incitations issue, so that their efferent fibres really convey motor incitations.

To this position I altogether demur. It is, in fact, a matter of the highest physiological and psychological importance that the correct view should be recognised and that a nomenclature which was, as I am disposed to think, entirely based upon an incorrect and mistaken view should be altogether discarded. There should be no half measures; the old view is either right or wrong, and if wrong it cannot be right to designate certain sensory areas of the cortex either as "motor" or "psycho-motor" centres, even though they are the cortical termini of ingoing impressions resulting from movements. I would put it therefore in this way:—

1. For the sake of physiological consistency, we should not call a cortical centre for afferent impressions "motor," *any more than we should call the cell nuclei on the sensory side of a spinal reflex arc "motor."* In each case they give birth to fibres which convey motor impulses, and in each case the stimulation of such internuncial fibres would give birth to definite movements.[1]

2. Again, the retention of any nomenclature which implies that the excitable areas in the cerebral cortex are "motor centres," tends to foster false physiological and psychological doctrines such as these:—

[1] As I have elsewhere said ('The Brain as an Organ of Mind,' 1880, p. 585):— "The plan on which nerve centres generally are constructed, of whatsoever grade, makes it essential that the stimulus which awakens the activity of a 'motor' ganglion or centre shall come to it through connecting fibres from a 'sensory' ganglion, centre, or knot of cells—that is, from cells which stand in immediate relation with ingoing fibres." The connecting fibres which I term "internuncial" *loc. cit.*, p. 586). Schiff speaks of as "kinesodic."

(*a*) The notion that we have in the sense of movement to do with a so-called "active sense," differing altogether in kind from other modes of sensibility ("passive senses"), seeing that its impressions are wrongly imagined to be "concomitants of the outgoing current."

(*b*) The notion that "mental operations in the last analysis must be merely the subjective side of sensory and motor substrata";[1] that we have such things as "motor ideas"; that "movement and sensation are the stuff of which our mental life is composed"; or that "at the root of our mental life, everywhere and always, there are movements."[2] If the activities of real motor centres are simple physiological processes (see p. 48) devoid in themselves of all psychical accompaniments, then the first phrase is an altogether erroneous one; while the subsequent phrases or statements are equally misleading, since they all imply that motor centres have such psychical accompaniments, and moreover confound them with the only real ideas of movement which we possess, viz., revived kinæsthetic impressions. As the writer has elsewhere said[3]:—"If the various impressions which go to make up the kinæsthetic sense are all of them (as we suppose) real 'ingoing' impressions that traverse different kinds of sensory nerves, the mere difference of the mode or occasion on which they are excited should not lead to them being spoken of as though they were radically different in nature from other sensory impressions. So that in accordance with this view, the dictum '*nihil est in intellectu, quod non fuerit prius in sensu,*' loses none of its old force."

It must not be supposed, moreover, that the evil consequences of the above-mentioned erroneous notions are limited to the spheres either of physiology or psychology. They are far-reaching in their effects. The associated doctrine, that words are revived in thought as "motor processes," tends, in my opinion, to throw confusion into the sphere of practical medicine by hampering the proper comprehension of the

[1] Hughlings-Jackson, in 'Clinical and Physiological Researches on the Nervous System' (reprint), 1876, pp. xx.–xxxvii.

[2] Ribot, in "Les mouvements et leur importance psychologique" ('Revue philosophique,' Dec. 1879).

[3] 'The Brain as an Organ of Mind,' 1880, p. 597.

great class of speech defects, and thereby, as I have attempted to show elsewhere, tends to check the advance of our knowledge of cerebral localisation in that direction.[1]

For all the reasons which have been above set forth, therefore, it seems to me to be a matter of extreme importance to recognize, that the excitable areas in the Rolandic and marginal regions of the cortex are in no proper sense of the term "motor centres," and that the evidence at present in our possession makes it extremely probable that they are termini for kinæsthetic impressions derived from muscles, so that their excitation in this or that region is the immediate precursor of this or that kind of voluntary movement.

DISCUSSION.

Dr. Ferrier.

Dr. Bastian has gone over much ground where it is unnecessary for me to follow him. I am, however, glad to be able to say, that in many points I am thoroughly in agreement with him, and in particular in all that relates to the sense of movement being dependent on centripetal impressions, and not on "outgoing" currents as contended for by Bain, Wundt, and others. I also admit that in the first edition of my work on the 'Functions of the Brain,' I used expressions in reference to the subjective aspect of motor substrata which appeared inconsistent with the views I had elsewhere enunciated on this topic; but I have made no change of front, and am glad that in the second edition of my work I have succeeded in clearing away any misconception that may have existed as to my real meaning, which is, that I consider that the activity of motor centres and motor nerves by themselves is entirely outside the sphere of consciousness. Their activity is revealed in consciousness only through the coincident functioning of sensory nerves and centres. But I must join issue with Dr. Bastian on almost everything else that he has said in reference to the nature and cortical localization of the "so-called" muscular sense. I use the expression "so-called," because I think it is a misleading term. What is merely a complex assemblage of impressions of different categories, has no claim to be regarded as a

[1] See p. 50.