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Original Articles and Clinical Cases.

HUGHLINGS JACKSON AS PIONEER IN NERVOUS PHYSIOLOGY AND PATHOLOGY.

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THERE is no honour of which I could be more sensible than that of being called upon by the Neurological Society to deliver the Hughlings Jackson Lecture; no task which I should undertake with greater pleasure than that of reviving my recollection of the nervous studies, which, in the early period of my professional life, constituted my greatest interest; no opportunity I could more cordially welcome than that of paying my homage of affection and respect to my old friend and fellow worker.

The interpretation which I put upon the duty entrusted to me by the Society is, that I should endeavour to set forth the principles in neurology established by Hughlings Jackson, and the reasons why, in this country, he is the acknowledged chief among neurologists.

This may seem to be but a humble task which I have set myself, but if I can get to the core of his teaching I do not think that I can render a greater service to neurology, whether as a department of practical medicine or as a branch of biological science, or that I can do better for the

younger generation of neurologists than to send them back to the study of the original writings, by which clear and definite ideas of nervous phenomena and nervous action were reached. We accept placidly the results of the labours of predecessors, but it is stimulating and inspiring to follow the steps by which order has been evolved from confusion, and to see pioneers wrestling with difficulties.

Hughlings Jackson has given to the world no such monumental treatise on diseases of the nervous system as that of Gowers.

We do not owe to him any such superb series of clinical and pathological descriptions and investigations as those which have made the name of Charcot illustrious.

He has not engaged in the experimental investigations into the functions of the different parts of the nervous system, which form the basis of nervous physiology, and from Bell onwards, in the hands of Claude Bernard, Majendie, Flourens, Brown-Sequard, Fritz and Hitzig, and Ferrier, to Horsley, Schäfer, Sherrington, Mott, and many others, have enabled us to understand the mechanism of the brain and cord.

He has taken no part in the microscopic unravelling of the intricate and complicated arrangements of cells and fibres, by means of which the nerve centres exercise their marvellous functions.

This makes it all the more extraordinary that, as is the case, we accord to him unanimously the first place among those who have contributed to neurology as a science.

The great reason is that he has been a pioneer in nervous physiology and pathology both in methods and results, has continuously raised our ideas of nervous action to a higher plane of thought, and has penetrated more deeply than even experimental science into the relations of the different nerve centres with each other and with the periphery, bringing to bear upon nervous physiology and pathology the speculations of evolutionary philosophy.

There are two kinds of knowledge, one consisting in the accumulation and verification of facts and their arrangement in their natural relation; the other of a more pro-

found character, comprehending the underlying significance of phenomena. It is this last to which Hughlings Jackson has so largely contributed.

The keynote to his teachings may be given in his own words. "The same fundamental principles apply to all nervous diseases whatsoever, from such as paralysis of an external rectus up to insanity."

All his writings are developments of this thesis.

Hughlings Jackson was the first in point of time to break through the barriers which experiments on animals had erected between the cerebrum and the lower nerve centres.

The motor or kinæsthetic functions of the cerebral cortex are now so familiar that we can scarcely imagine that any question could be entertained with regard to them, but when Hughlings Jackson entered upon the study of nervous diseases he was faced by the experimental facts that when the hemispheres were sliced away there was no evidence of loss of any particular faculty, but a gradual diminution of volition, that the hemispheres could be removed altogether, apparently leaving the motor apparatus of the nervous system intact, that the headless frog turned over when laid on its back, jumped, and rubbed vinegar off its back, that the pigeon with its cerebral hemispheres removed, while inert and impassive, walked when pushed and flew when thrown in the air, that the rabbit, deprived of its brain, started at a noise, screamed when pinched, hopped in a natural manner when pushed. The conclusion seemed inevitable that the brain proper had nothing to do with movements.

Hughlings Jackson anticipated the experimental demonstrations of Hitzig and Ferrier and showed that the experiments made by disease could be used in the interpretation of the anatomy and physiology of the nervous system, and that movements could be induced by the excitation of portions of the cerebral cortex, the removal of which did not give rise to paralysis.

The two great subjects with which his name will always be associated are the study of convulsions, with the elucida-

tion of epilepsy to which this study led, and the theory of evolution and dissolution as applied to the nervous system.

When he first gave his attention to the question of convulsions no definite ideas were entertained as to their causation, and it would be extremely interesting, were there time, to follow the stages by which he reached the conclusions with which we are now familiar.

He has informed us that the origin of his special investigations on epilepsy was a case in which right unilateral convulsion was followed by temporary defect of speech, and we find him saying, in the comments on a case of this kind reported in the *Medical Times and Gazette* as early as August, 1864, that the brain substance must be temporarily ill-nourished by inadequate blood supply, just as it would be permanently damaged by plugging of the arterial trunk. In the first we have unilateral convulsion, in the second, unilateral paralysis, hemiplegic epilepsy, and epileptic hemiplegia respectively. Convulsion, he continues, is closely allied to paralysis—paralysis often follows convulsion and convulsion often begins in parts already paralysed.

Chorea also, especially hemichorea, was shown to teach the same lesson, that irregular movements and paralysis of a given set of muscles indicate lesion of different degree in the same nerve centre.

In April, 1866 (*Medical Times and Gazette*), he already considered the term epilepsy to imply not simply liability to convulsive attacks, but to include sudden and temporary loss of function of any nerve centre, loss of sight, of consciousness, of speech, spasm of hand, face, or leg, and to have as its cause an affection of the nervous tissue in a particular arterial region, and in 1867 (*Lancet*, "Regional Palsy and Spasm"), while speaking of genuine epilepsy as an insoluble problem, he proposed to begin the investigation of it with a simpler form of convulsion and to try and find out what condition of the nervous matter it was in a particular part, the corpus striatum, which permitted occasional spasm of the muscles which this part empowers, and to study phenomena so as to get to know the portions of the nervous centres, affection of which was attended with sudden (1) loss

of speech for a while, (2) coloured vision, (3) spasm of arm, (4) smell, (5) transient loss of consciousness, (6) sudden fury, (7) convulsions.

Auræ were the first outward signs of the first local changes inside, and just as unilateral palsy and spasm were contrasted he would contrast these. As in hemiplegia we endeavour to ascertain the nature of the local lesion which has given rise to the paralysis, so we should inquire into the nature of the morbid change giving rise to convulsion.

In 1868, in a paper on the physiology of language (*Medical Times and Gazette*) is the first mention of evolution which I have met with.

Even the work of an ordinary kind which Hughlings Jackson has done in connection with diseases of the nervous system has not been done in an ordinary way, and his records of cases are illumined by flashes of insight which make the perusal of them interesting and profitable. Instances are his early recognition of syphilis as a cause of disease in the nerve centres through gummata in the pia, and through vascular lesions, the remarkable collection of cases illustrating localising lesions in the bulb, pons, and crura cerebri, the examples of unilateral convulsions of cortical origin, the illustrations of the association of right hemiplegia with loss or defect of speech. In 1864 he had already seen seventy cases of loss or defect of speech, in all except one of which there was hemiplegia on the right side, and had arrived independently at the conclusion that the left hemisphere was specially concerned in speech, all but anticipating and certainly paving the way for the immediate acceptance of Broca's localisation of the downward starting point for words. Mention also must be made of his early and persistent advocacy of the routine use of the ophthalmoscope and of his discussion of the significance of optic neuritis and its relation to intracranial disease.

It is scarcely work of an ordinary kind which is found in his lecture on the study of diseases of the nervous system in the *London Hospital Reports* for 1864.¹ In it he inculcates the practice which he himself always followed, and which in his hands has led to the elucidation of so

¹ *Vide post*, p. 367.

many nervous problems, that the observation of nervous symptoms must not only be *minute* but *precise*, and lays down the rule, now familiar to everyone, that we must pursue three distinct lines of thought in investigating nervous diseases with regard to :—(1) Disease of tissue ; (2) damage to organ ; (3) disorder of function ; or, as he puts it elsewhere, consider separately their pathology, anatomy and physiology.

From the symptoms, which are physiological, we infer the locality of the lesion, which is the anatomy, and then by a distinct and separate investigation endeavour to identify the character of the change in the nutrition, which is the pathology.

CONVULSIONS.

We may now try to follow Hughlings Jackson in the study of convulsions with which his name will ever be associated. The fundamental ideas are that all nervous action is of the nature of a discharge and that movements are represented in the cortex of the cerebral hemispheres as well as in the lower centres, and can be excited by discharge taking place in regions of the cortex, destruction of which does not give rise to paralysis. The term discharge is borrowed from electrical science, but its essential character is chemical and of the nature of an explosion, a sudden readjustment of molecules with liberation of energy. There is accumulated in the nerve centres a substance having what I called many years ago chemical tension, in virtue of which it is ready to explode on the application of an appropriate stimulus. In normal nervous action, sensory or motor, the liberation of energy, or discharge, is orderly, limited in amount and strictly adjusted to the stimulus. In convulsion the discharge is sudden and excessive, and disorderly, the seat of the abnormal discharge determining the starting point and course of the convulsive movements, its suddenness and excess, their violence and extent. Suddenness is an essential feature of the convulsive discharge, and it is largely in consequence of its suddenness that the ab-

normal discharge is not limited to the unstable cells in which it begins. The violence of the explosion in them excites discharge of all the cells within reach, not only downwards toward the muscles, but possibly upwards and certainly collaterally. In general convulsions, in which the initial explosion is in some part of the highest centres in one hemisphere, its effects are propagated to other parts of the same hemisphere, and to the opposite hemisphere, as well as downwards. The study of convulsions, therefore, becomes extremely important, not simply from the point of view of verifying their conformity to a given type, but as departures from the normal functional activities of certain nerve centres. The starting point, march, and order of the movements must be precisely noted. It was through this study of convulsions that epilepsy was rescued from the category of so-called functional nervous diseases—functional, that is, in the sense of having no recognised pathology or reasonable explanation. From the fact that an undue degree of vascularity was found in the bulb in epileptics it was inferred that this part of the nervous centres was the seat of the disease, a conclusion supposed to be confirmed and rendered practically certain by the experimental evidence that convulsions were possible when the cerebral hemispheres had been removed. A view so supported and in accord with the generally accepted idea that the cerebrum had no motor functions was not easily overthrown, and it is Hughlings Jackson's incontestible merit to have subverted it, and substituted the doctrine now held with regard to epilepsy. The wedge driven into the old theory was the demonstration that unilateral convulsions of the kind now appropriately known as Jacksonian epilepsy were due to a lesion in the cortex in the Rolandic area, and this it should be understood took place before Fritz and Hitzig's experiments had shown that the electrical irritation of these gyri gave rise to movements. As has been already stated, it was a case of right unilateral convulsion followed by temporary defect of speech which suggested his special investigation of epilepsy. The convulsion must, he inferred, have been due to some affection of the same region, destruction of

which produced permanent loss of speech. In both the cause was embolism, in one case giving rise to a destructive lesion, to instability in the other.

EPILEPSY.

One of the great lessons we have learnt is that in approaching the scientific study of epilepsy—and the same may be said with regard to all nervous disease—we must be intent not on noting the conformity of the attacks to a type, but on a precise observation of the departures from normal modes of action which they exhibit.

Another is that epilepsy presents exactly the same problems for investigation as other diseases of the nervous system and the same basis of classification, physiological, anatomical, and pathological—the deviations from normal function presented by the symptoms, the seat of the lesion—the particular nervous centre, affection of which gives rise to the abnormal manifestations—and the nutritive or structural change which has taken place in the nerve centre and which underlies the liability to the special form of functional error.

The idea of epilepsy which we owe to Hughlings Jackson is that epilepsy is the occasional, sudden, excessive, violent discharge of some nerve centre, sensory or motor.

The immediate cause of the paroxysmal tendency is instability of the explosive constituent of the nerve centre in which the initial discharge takes place and it is conceivable that there may be, on the one hand, excessive formation, or, on the other, defective quality of the explosive material. In the latter case the constitution of the molecule may remain the same, while its composition is altered by the substitution of an element or molecule of lower affinities. Studying the conditions under which instability arises they are best illustrated by the lesions in the Rolandic convolutions which give rise to Jacksonian epilepsy. With or without destruction of nerve elements there is congestion, an excess of blood in the capillaries with retarded motion and consequent modification of the nutrition of surviving cells. The chorea

of acute rheumatism associated with capillary embolism furnishes another illustration of instability of nerve-cells induced by interference with the circulation in the nerve centres. When, as in ordinary epilepsy, no morbid change is apparent, it must be assumed that the nutrition of the gray substance is modified so as either to give rise to excessive production of normal explosive matter or to formation of a deteriorated and more unstable variety. According to the degree and character of the exaggerated or perverted nutrition will be the intrinsic epileptic tendency, and its dependence upon or independence of etiological influences or exciting causes with regard to the frequency and violence of the fits. And since there are many nerve centres there are many epilepsies.

They may be divided into (1) epilepsy proper, in which the initial explosion takes place in some part of the cerebral cortex other than Rolandic convolutions; (2) Jacksonian epilepsy; (3) ponto-bulbar epilepsy.

I have here deviated from Hughlings Jackson's nomenclature. He could not perhaps employ the term Jacksonian to designate the unilateral convulsions beginning without loss of consciousness, which, in his hands, have thrown so much light on epilepsy and on the physiology of the cerebrum; at any rate he has never done so, but has always called them epileptiform. We need the term epileptiform, however, in general medicine as a ready method of indicating the general convulsions, which may occur in uræmia and from numerous other causes. It is not, again, strictly accurate as applied to convulsions which differ essentially from those seen in epilepsy. The appellation Jacksonian is generally accepted, and it has the advantage of a definite connotation, which obviates the necessity of falling back on the word "fits," while it is a permanent expression of the homage which the neurological world delights to render to Hughlings Jackson. It was a happy inspiration which led Charcot to employ this designation.

Pursuing the ideas indicated, it follows that the hemispherical cortex outside the so-called motor area being the seat of the complex activities which are concomitant with

the highest mental operations, sudden loss of consciousness without warning would indicate discharge of some part of these convolutions. If motor phenomena predominated at the outset, *e.g.*, a pirouette of three turns, as in a case under my care, the starting point or initial discharge would be in the anterior part of the hemisphere; if sensory coloured vision, stunning noise, a foul odour, the initial discharge would be posterior. The occurrence of convulsions in *grand mal* is determined by the suddenness and violence of the discharge or explosion, which is such as to overcome the resistance of centres in the same and in the opposite hemisphere, discharging them.

When there is an aura this will be the first outside indication of the commotion taking place inside, and will afford a clue to the particular centre which is the seat of the disturbance.

A feature of fully developed epileptic paroxysms is the unconsciousness or coma which follows the convulsion. This represents paralysis of the highest centres presumably from exhaustion. Whatever the cause, however, exhaustion or other condition, coma is paralysis; from another point of view it is a temporary insanity—*amentia*.

In *petit mal* it is still in some part of the highest cortical centres that the discharge takes place. From the feebleness of the explosion, however, or perhaps in some cases from its slowness, it is only collateral cortical centres, in the same or in both hemispheres, which are discharged, and the explosion does not take effect on the lower centres except perhaps, on a few centres for delicate movements such as rolling of the eyes, twitching of the face or fingers. These, which are genuinely convulsive in character, must not be confused with such actions as smacking of the lips and swallowing, which are motor reflexes from discharge of the gustatory or olfactory centre.

An attack of *petit mal* may be followed by maniacal excitement or by highly complex purposive actions, often very absurd, or by temporary mental confusion. These are not a part of the fit, but are consequences due indirectly to paralysis of the centre in which the fit started, to partial

loss of consciousness, with suspension of the influence of some one or more of the highest centres, and unbalanced or uncontrolled or excessive functional activity of collateral or lower centres.

An interesting set of epilepsies, both *grand* and *petit mal*, has been called the uncinæ group of fits. These cases are characterised by a warning relating to the digestive system, a foul odour, a crude sensation of taste, an epigastric sensation, or by reflex movements excited by discharge of the gustatory centre, such as smacking the lips, tasting movements of the tongue, champing, spitting, or swallowing. The localisation is not merely suggested by the fact that the uncinæ lobule is the olfactory and gustatory centre and by paralytic counterpart to the spasm, but has been verified by *post-mortem* evidence, in one case a focus of softening having been found in the uncinæ gyrus, in others tumours involving the anterior part of the temporo-sphenoidal lobe. The comparatively slight movements have a very important significance as they determine the epileptic character of light attacks which otherwise might seem to be trifling.

A curious fact is the frequent association of intellectual or emotional affections with uncinæ fits, the dreamy state, mental diplopia, a sense of fear or horror. This dreamy state, which assumes various forms, is not an aura in the same sense as a crude sensation, but is the effect of a slight cortical discharge. The mental diplopia or double consciousness may possibly represent a discharge which affects one hemisphere only, not reaching the other, and there may thus be normal consciousness in one half of the brain and a slight defect of consciousness in the other.

Vertigo of a sudden fulminating character must be considered to come within the comprehensive definition of epilepsy, even when primarily ocular or auditory, as well as when more strictly epileptic.

Migraine may perhaps be regarded as a sensory discharge of cell-elements in the cuneal region of the cortex.

(2) In Jacksonian epilepsy the lesion, which is usually of a coarse character, thrombosis, syphilitic disease, tumour, is

definitely localised in the Rolandic convolutions. The distinctive feature of this form of epilepsy is that the convulsion begins unilaterally and precedes loss of consciousness, should this occur. While the lesion is obvious and often extensive, the fits are not to be attributed to its destructive effects, but to the modified nutrition and exaggerated instability of neighbouring nerve-cells resulting from the interference with the capillary circulation.

With regard to Jacksonian epilepsy, it is only necessary to call to mind that the convulsion starts in the part of the limb or face which is most employed in fine or complex movements, the hand, and in this the thumb and the index-finger, the parts about the mouth in the face, the great toe in the foot; that it may be (1) limited to these parts, or (2) extend to the whole of the limb without loss of consciousness, or (3) spread to other limbs, in which case the march of the convulsion is upwards in the limb first affected and downwards in the others. Loss of consciousness usually attends such extension, and when the original discharge is sudden and violent the sequence of events may be so rapid that the fit simulates a true epileptic attack.

More or less temporary paresis of the limbs in which the convulsion began follows the attack and sometimes a certain degree of anæsthesia. It is noteworthy that there are never mental phenomena.

An interesting fact of far-reaching import is that convulsion beginning in the hand or foot can often be prevented from travelling up the limb by a ligature or by powerful friction. A powerful sensory impression inhibits the extension of the cortical discharge. The subsequent paresis is apt to be intensified when this has been done.

While epilepsy proper and Jacksonian epilepsy are due to explosive discharge of cortical and cortico-central centres, it was inferred that there might be epilepsies from discharge of bulbo-spinal centres and that these would exhibit special features. Experiments on animals had shown that convulsions might occur when the cerebral hemispheres had been removed, even in the case of the remarkable Brown-Sequard convulsions provoked by irritation of the fifth nerve after hemisection of the cord in the guinea pig.

At first bulbo-spinal epilepsy was considered to be represented by laryngismus, but other forms have been identified.

Several cases have been recorded resembling those artificially produced in guinea pigs. In one brought before the Medical Society and published in the *Lancet* for February 2, 1895, a boy of 7 fell down in a fit whenever his head or face was unexpectedly touched, but not if he knew beforehand. He turned red, looked vacant, his respiration stopped, his eyes were turned to one side, and he would fall if not caught. In some attacks he screamed. It must be specially noted as belonging to the ponto-bulbar seat of the disease that arrest of respiration was a marked early feature of the fits, and it was observed also that he was drawn down by muscular action, *i.e.*, by contraction of the trunk muscles, rather than fell. He remembered nothing of the attacks.

Another form of ponto-bulbar fit is described in BRAIN, Spring, 1902, by Hughlings Jackson and Dr. Douglas Singer. The attacks were frequent and began with simultaneous tonic spasm of the muscles of the neck on both sides, back and front, of the jaws, of the face on both sides, while the thorax was fixed in a position of partial expiration. After a few seconds there was clonic spasm of the same muscles, there were no movements of arms or legs, no change of colour, no sweating. At another stage fits beginning with fixation of the chest involved the muscles of the face, chest, body and upper limbs; in the arms the order in which the muscles were involved was from the shoulder downwards.

Cerebellar epilepsy may perhaps be represented by the sudden opisthotonic spasms which have been observed in some cases of tumours of the cerebellum.

EPILEPSY—PATHOLOGY.

There still remain to be given Hughlings Jackson's views on the pathology of epilepsy. They are that, just as certainly as Jacksonian epilepsy is due to a lesion in the Rolandic gyri, so are epileptic attacks proper the result of a deviation from normal nutrition in some part of the hemi-

spherical cortex other than these convolutions. That the altered nutrition is local, and not vaguely distributed over the entire hemisphere, is shown by the fact that in a given case of epilepsy the fits practically always resemble each other, more particularly in the most important point, their mode of onset. The effect of the nutritional error or morbid change is, as has been already said, instability of a greater or lesser number of nerve-cells, either from excessive formation of the normal explosive constituent, or, as I think more probable, from the formation of a lower grade of explosive matter, which is more unstable. It is possible that the morbid change is primarily and inherently in the nerve elements themselves, but more probably it is a secondary effect of some affection of the non-nervous structures which enters into the construction of the nerve centres. Circulatory conditions certainly play an important part, and the distribution of the altered nutrition seems to follow vascular areas. There are undoubted illustrations of instability from interference with the blood supply, by capillary embolisms in certain forms of chorea and in the congestion around coarse lesions in the Rolandic convolutions. Blood moves more slowly and is detained longer in the affected area. It may be assumed also that in epilepsy caused by thickening of some part of the cranial vault or by pachymeningitis, the cortical circulation is retarded by the pressure. No change may be discoverable by the microscope.

The exciting cause of individual paroxysms is often cardio-vascular, as is suggested by the frequency of epileptic fits during the night and in the early morning, when the circulation has run down. In other cases the intestine or uterus, or other organ or sentient surface, may act the part of an epileptogenous zone.

EVOLUTION AND DISSOLUTION.

While the establishment of the motor endowment of the Rolandic area of the cortex by means of experiments performed by disease, and his elucidation of the true nature of

epilepsy are perhaps Hughlings Jackson's greatest and most permanent achievements, his theory of the nervous system as an example of a great evolutionary process and of nervous diseases as examples of dissolution is the most original and comprehensive.

Another keynote may here be quoted :

"Every nervous disease being a flaw in one great evolutionary system demands consideration as wide as we can make it with precision."

From this point of view no symptom is devoid of significance.

The relation between the nervous system and the body generally is characterised as representation. Every part is represented in the nerve centres.

Three levels of evolution in the nervous system are described, exemplifying von Baer's law of progress from the general to the special in function, and from the simple to the complex in structure. The lowest level is constituted by the cord and bulb, by those centres in which the representation of impressions and movements is direct and comparatively simple. We must always bear in mind the acute and profound distinction that it is movements, not muscles, which are represented, impressions, not sentient surfaces. The motor nerve centres do not concern themselves with the instruments ; they represent chords, not notes.

While the representation of impressions and movements, or, as we may now say, sensori-motor processes in the lowest level, is direct, the range of the processes may be very extensive. The cardiac and respiratory rhythms are organised in this lowest level at birth, and with them such highly complex respiratory acts as crying, sneezing, coughing. So, again, are the instinctive act of sucking and the reflexes by which food is carried along the intestinal canal, and those by which the bladder and rectum are evacuated. Other illustrations of highly complex and extensive sensori-motor actions organised in the lowest level at birth are the closing of the fingers when the palm of an infant is tickled, and the extraordinary prehensile power which is exhibited in the infant's hands when a finger is placed in each, the grasp being such that

the child can be raised from the ground. There must here be in action not only the flexors of the finger and thumb, but the synergic extensors of the carpus which Dr. Beever described in his Croonian Lectures.

However complex the movements originating in the lowest level may be, they are, so to speak, automatic, the response to an impression is definite and constant, and, as an impression increases in force and the motor response becomes more extensive, the radiations by which the afferent energy is distributed follow definite lines. The sensori-motor apparatus is organised, the sensori-motor action is automatic.

Since this lowest level is employed by higher centres, there run longitudinally in the cord and bulb not only intrinsic fibres connecting the different lowest level segments, but fibres, afferent and efferent, which connect all parts of the cord and bulb with the cerebrum and cerebellum, and, inasmuch as they do not form part of the mechanism of the lowest centre they may be called extrinsic.

The middle evolutionary level is constituted in Hughlings Jackson's scheme by the central ganglia and the convolutions in immediate relations with them. On the motor side these have been believed to be the Rolandic convolutions posterior as well as anterior to the sulcus, but this opinion may have to be revised in view of the recent experiments of Sherrington and Grünbaum, which seem to restrict motor function to the gyrus which ascends in front of the sulcus.

In this level, impressions from every sentient surface or organ and movements effected by all the muscles of the body, voluntary or involuntary, striped or unstriped, skeletal or visceral, are again represented, or rather, as Hughlings Jackson expresses it are re-represented, and not movements only, but glandular activities and thermal regulation must be thus represented.

The impressions which reach this level are re-representations of impressions made directly upon the lowest level, and the movements are re-represented by combinations of the motor representations existing in the lower level.

Movements best lend themselves to illustration of the

higher stages of evolution, and there are:—(1) increasing complexity—representation of a greater number of different movements; (2) increasing specialisation—representation of movements for more particular duties; (3) increasing integration—representation of movements of wider ranges of the body in each part of the centres; (4) more numerous intercommunications of the units (co-operation).

The automatism is less distinct, the mechanism less definitely organised. And, as is said by Herbert Spencer, "The cessation of automatic action and the dawn of volition are one and the same thing."

Elsewhere (Croonian Lectures) he speaks of evolution as (1) A passage from the most to the least organised—from centres comparatively well organised at birth to those, the highest centres, which are continually organising through life. (2) A passage from the most simple to the most complex. (3) From the most automatic to the most voluntary. If we take most organised to apply to the structural arrangements, most reflex would describe the functional action.

As an illustration of the increased complexity and less definitely organised automatism of movements represented in a higher level, we may take the numerous and complex movements of the hand, fore-arm, arm, shoulder, and trunk, which enter into such an action as the raising of a glass to the lips. Each of them is represented individually in the cord, and they are collectively re-represented in a complex and coördinated way in the central ganglia and Rolandic convolutions. Then as this simple act can be accomplished by a great variety of sequences and combinations of movements, so a potentiality of different coördinations and combinations exists in the middle evolutionary level, by means of which the spinal motor centres of the fingers and other parts of the limb can be called into varied but orderly action.

It is in the middle level that visual impressions are, on the one hand, coördinated with tactual impressions so that they come to correspond as to form, size, and distance of objects, and, on the other, are brought into relation with the

motor apparatus of the lowest level, so that movements may take place under the guidance of vision.

Another question presents itself for consideration. It is in the middle level that activities of the nerve centres first become associated with concomitant states of consciousness. Vision implies consciousness. Visual impressions in addition to the complicated associations which they form with the motor side of the nervous apparatus, by means of which they guide movements, are also referred to a receptive centre, their impact on which is associated with the emergence of that element of a state of consciousness which we call a visual perception.

Different doctrines are held with regard to the relation between psychical operations and nervous activities:—(1) That the mind acts through the nervous system; (2) that activities of the highest centres and mental states are the same thing or different sides of one thing; (3) that states of mind or consciousness are different from nervous states of the highest centres, and that while they occur together there is no interference of one with the other. It is this last which Hughlings Jackson accepts. The functions of the cerebral hemispheres are assumed to be the coördination of impressions and movements. It is true that the cerebral hemispheres are the physical basis of consciousness and mind, but this is in virtue of the fact that in them are represented innumerable impressions and movements of every part of the body. It is true again, as Herbert Spencer says, that mind and nervous action are phases of the same thing. We can think of matter only in terms of mind. We can think of mind only in terms of matter. But for Hughlings Jackson states of consciousness or mind are utterly different from nervous states and, while the two things occur together or in parallelism, there is no interference of one with the other but only concomitance. A visual image arises *during* not *from* activities of the eye and brain. There are not four separate faculties, will, memory, reason, emotion, but four artificially distinguished aspects of states of consciousness.

We may not be able to follow him in this high degree of

abstraction but we cannot too constantly bear in mind that in disease it is structure and function of nervous centres with which we have to deal and not mental faculties, that for example, it is no explanation of speechlessness to say that the patient has lost his memory for words.

The highest level which constitutes the physical basis of mind is constituted by the cerebral cortex generally other than the convolutions which have been experimentally identified as forming the middle level (the motor centres in the Rolandic region, the sensory centres in the angular or calcarine gyri for vision, the first temporo-sphenoidal gyrus for hearing, the uncinate lobule for smell and taste). In these convolutions which receive or emit no radiating or callosal fibres, evolution is carried still further, movements and impressions are in them re-represented. (1) The complexity, (2) the specialisation, (3) the integration, (4) the intercommunications, are all carried to a higher power. It is here that the final adjustment of the organism to its environment is effected. The concomitant states of consciousness associated with activities of these convolutions will be abstract ideas, flights of imagination, exercise of the higher reasoning faculties, volitions. These expressions are no doubt wanting in exactness and philosophical precision, but they will not mislead, if we bear in mind the mutual independence of states of consciousness and nervous activities.

Hughlings Jackson holds that not only does the highest level of evolution as a whole represent all impressions and all movements, but that each individual part of the highest centres potentially represents all impressions and movements generally, while representing some impressions or movements more particularly. The pre-frontal convolutions he considers to be the highest motor centres, the posterior extremity of the hemispheres the highest sensory centres. Compensation, the gradual recovery of power after paralysis, he explains from a like point of view; movements represented in destroyed parts are represented, though in somewhat different order, in surrounding parts.

Returning now to the consideration of the relations between the different levels, (1) they are subordinate one to

the other from below upwards, the middle level calling into action in various combinations the motor centres of the lowest level and receiving and coördinating different impressions from this level; the highest level in turn receiving the impressions elaborated in the middle level and initiating sensori-motor impulses which are transmitted downwards, and so to speak translated into appropriate movements by the middle and lowest levels.

(2) Each level is a reservoir of energy capable of independent discharge, and the same may be said of every centre in all three levels. The higher levels, however, not only make use of the lower levels by stimulation and discharge of appropriate portions, but they also exercise control over them and inhibit irregular purposeless discharges. This control or inhibition is of the greatest importance when the effects of dissolution in higher levels is considered.

(3) Further the centres in the different levels are not only reservoirs of energy but positions of resistance. They enjoy a certain degree of independence and each level can resist impulses, afferent or efferent, reaching them from other centres, lower or higher. When, for example, we have ideas and imagination and recollections passing through the mind, these faint states of consciousness are the concomitants of slight activities of the highest centres which do not overcome the resistance of the middle and lowest levels so as to be propagated downwards, and do not, therefore, result in sensori-motor actions. On the other hand the highest level is protected from all but the more vivid afferent impressions by resistance to their transmission from the lowest to the middle and from the middle to the highest. New adjustments and combinations of impressions and impulses can thus be made and tossed about from one convolution to another without interference from below. These may constitute an advance in evolution which may even go on during sleep.

This idea of the mutual resistance between the different levels and centres may be extended. All parts of the nervous system, in my opinion, hold each other in mutual tension, and the passage of an impulse, afferent or efferent,

is better represented as a disturbance of an equilibrium of forces than as a transmission of energy. There is a state of mutual tension between the nerve-endings in sentient surfaces and in muscles and the sensory and motor nerve nuclei in the spinal cord as well as between one nerve centre and another.

It is when the effects of dissolution are considered that the insight evinced in the doctrine of evolution becomes manifest and we see the force of the corollary that "every disease being a flaw in a great evolutionary system demands consideration as wide as we can make it with precision, from paralysis of an external rectus up to insanities." The investigation must not only be minute, but precise. From this point of view no symptom is devoid of significance, the order and march of the symptoms as well as their character are important.

The applications of the doctrine of dissolution to the effects of disease of the nervous system are profound and far reaching. Dissolution implies the reversal of the process of evolution, or descent from the least definitely organised, most complex, and most voluntary, towards the most definitely organised, most simple and most automatic.

Dissolution may take place in any of the evolutionary levels. When this is the case the functions of the centre in which the lesion has occurred are suspended and corresponding symptoms which may be called negative are observed. These, however, are not the only symptoms; other symptoms, usually more obtrusive and often infinitely more important, are produced by the activities of other centres, either *A*, unbalanced in consequence of the absence of normally opposing activities, or *B*, liberated from the control of higher level centres, or *C*, intensified by attempts to compensate for the missing function. Illustrations of indirect effects of this kind are among the most illuminating of Hughlings Jackson's contributions to neurological science. A simple but striking one is furnished by paralysis of the external rectus. There is, of course, double vision but this is not all. In the attempt to carry the affected eye outwards a more powerful stimulus comes to the nerve

nucleus from the higher level but this only takes effect on the associated internal rectus of the other eye. This may or may not exaggerate the double vision according as the object remains within the range of both eyes or is visible only to one, but the position of the eyes being judged of according to the strength of the stimulus issuing from the higher level, an erroneous projection ensues, the object is misplaced in consciousness; and the movements of the body and limbs being adjusted to this false position of surrounding objects, vertigo and staggering are produced.

Examples of simple reduction from voluntary action towards automatism are afforded by the ordinary form of hemiplegia in which the arm is most and longest paralysed and of this limb the fingers and hand, the leg less, the face partially, the bilateral more automatic movements being spared. And also by aphasia in which there is loss of intellectual—the more voluntary—language with persistence of emotional—the more automatic language; impairment of pantomime which is intellectual, while gesticulation which is emotional is unaffected.

“Yes” and “no,” which can frequently be said distinctly and appropriately are most general and most automatic. While conveying assent to or dissent from a proposition they indicate an attitude of mind rather than an intellectual act.

Other examples are given but they would require explanation.

Coma and unconsciousness indicate dissolution in the highest level extending in extreme instances to the middle level and to the lowest level, with the exception of the cardiac and respiratory reflex centres.

The most interesting and important illustrations of dissolution are those in which a centre in the highest level is paralysed and symptoms arise from the action of other centres in the same level or in another level. Examples are post-epileptic dreamy states, cerebral diplopia, unconscious actions which may be elaborate and quite purposive, or maniacal excitement. Here the centre in which the discharge has started is left exhausted or, for the time being,

paralysed. The active symptoms result from the activities of other centres on the same level in the same or in the other hemisphere, more or less normal, but unbalanced by the centres paralysed, or from uncontrolled activities of lower centres which are habitually under inhibition by the centres whose functions are in abeyance, or from what Hughlings Jackson calls superpositive activities of various centres, which may result from attempts at compensation comparable to the over action of the internal rectus of one eye when the external rectus of the other eye is paralysed.

Insanity becomes much more comprehensible when considered from this point of view.

But we have to speak of insanities just as we have had to speak of epilepsies, and among the insanities must be included not only permanent or durable mental aberration, but such conditions as drunkenness in its various stages, the delirium of fever, coma, or unconsciousness, however produced. We are thus able to make use of post-epileptic nerve disturbances in the elucidation of insanities.

Speaking of them comprehensively there is dissolution, general or local, in the highest levels of evolution, and the depth or degree of dissolution will vary as well as the situation and extent. This is attended with a corresponding degree of paralysis, which, supposing the dissolution to have taken place in the highest level, will mean loss or impairment of the reasoning power, of the finest emotions, of the adaptation to present surroundings. But this paralysis of centres in the highest level will leave unimpaired and uncontrolled collateral and lower level centres, and their activities, normal or intensified, will be responsible for the active delusions and insane actions which constitute the insane manifestations.

Dissolution going deeper will be attended with greater loss of mental power and fewer evidences of functional activity of lower levels till we arrive at dementia.

Drunkenness in different degree illustrates the whole process of general dissolution gradually reaching deeper layers. Alcohol, like the anæsthetic gases, affects the nervous centres from above downwards. At first the

pareisis of the highest level impairs the judgment and self control, the man is regardless of his surroundings, this is the negative side of his condition. On the other hand he is garrulous, in high spirits, excitable, easily moved to mirth or anger. In this we have the play of lower centres no longer under due control, or he may be boisterous and quarrelsome or amatory. The effects of alcohol on different men are very different. This may, in part, be due to greater susceptibility of one centre in the highest level to another in different individuals, but more commonly it is the underlying essential character which is laid bare and in *vino veritas*. As the dose of alcohol is increased the dissolution goes deeper, the man becomes stupid and maudlin and fails altogether to appreciate what is going on around him, his speech is confused, his utterance thick—all indications of a further degree of paralysis. He is no longer garrulous and argumentative but probably repeats the same thing over and over again; his emotions may break loose and he may become the subject of uncontrollable laughter or weeping. The lower centres still capable of functional activity are, even when set free from control, only competent to the production of general and automatic actions. Carried still further the alcoholic poisoning reaches the stage of coma or stupor, the man is dead drunk. The centres of all the levels are paralysed except those in which the cardiac and respiratory reflexes are carried on—there is almost complete dissolution.

There would not be time, even were our knowledge ripe for it, to discuss the insanities due to local dissolutions. One suggestion only need be mentioned; that general paralysis of the insane is due to dissolution affecting the pre-frontal convolutions, melancholia to dissolution affecting the posterior part of the brain.

In all dissolutions the rate at which the functional efficiency is abolished will greatly influence the symptoms which result. A cortical change, which, taking place suddenly, gives rise to acute mania, would have no such effect if brought about slowly.

The form and degree of insanity arising from a given

depth and seat of dissolution, again, will vary with the original character of the system of the nervous system in which it takes place, and the degree of evolution which it has attained through education and circumstance.

The factors of the insanities then are:—

(1) Dissolution, varying in situation, extent, and depth, of the highest nerve centres.

(2) The person who has undergone this dissolution of his nerve centres, whether a child, adult, or aged individual, whether originally clever or stupid, educated or non-educated.

(3) The rate at which the control of the highest centres has been withdrawn.

(4) The influence of local bodily states and of external circumstances.

The position of the senses of hearing and vision in the evolutionary system has not been fully discussed by Hughlings Jackson, and the question is a difficult one. The nucleus of the auditory nerve in close relation with the nuclei of the vagus, trifacial, &c., in the floor of the fourth ventricle, obviously belongs to the lowest level. Its lowest level sensori-motor relations seem to be, however, extremely simple. A loud noise provokes a general start, but this is common to any violent impression; there may be an automatic turning of the head and ears in the direction of a sound, and there is the adjustment of the tension of the membrana tympani to sounds of different pitch, which are practically all. A very remarkable fact, the significance and object of which must be important, but are not yet fully comprehended, is the close association between the cochlear or auditory nerve proper and the nerve from the semi-circular canals, which is concerned in the equilibration of the body. Hughlings Jackson points out the impulse to dancing and other rhythmical movements excited by music, which may be almost irresistible, as in some way an effect of this association, but there must be something further.

It is doubtful how far vision can be said to belong at all to the lowest level. The only automatic responses to visual impressions are the pupil reaction to light, the accommodation to near and distant vision and the quasi-involuntary following of objects by the eyes.

The geniculate bodies and corpora quadrigemina which form the apparent terminations of the optic tracts cannot be said to belong to the pons, even if they could be considered to be the nuclei of the optic nerves, which is more than doubtful, and it must be remembered that the optic ganglia in the articulata are supra-oesophageal.

The retina is a combination of peripheral and central structures; while its inner layer in contact with the vitreous is a highly specialised portion of the integument, its outer layer is formed from a vesicular protrusion from the mid brain.

Vision, as a part of the higher evolutionary level, has two distinct relations. The greater part of the most purposive movements are performed under the guidance of visual impressions and visual images are the starting point of intellectual operations. These, in my judgment, must be held to be quite distinct functions. A visual image implies a state of consciousness, the guidance of movements may be effected without emergence in consciousness.

While vision directs movements, movements of every possible kind can be organised independently of sight, as is seen in the case of the blind. We cannot, therefore, say that visual cell groups arrange and control the motor cell groups in the higher level, by means of which the elaborate combinations of movements are executed. These higher level motor cell groups must be organised by higher level sensory cell groups re-representing impressions from the sentient surfaces, muscles, joints, &c. Visual sensory impressions thus find them ready for employment. But granting this, fibres must still pass from the visual centre to the motor cell groups to call them into action which will be efferent fibres of the optic sensori-motor apparatus.

A very important correlation must be effected between tactile and visual impressions in order that the representations and re-representations received from the two sources may correspond. Here again on the sensory side re-representations of tactual impressions must be antecedent to visual representations. Accurate ideas of form and size are formed by the blind, and visual impressions must be

interpreted by the antecedent tactual impressions. Where exactly and by what cell and fibre mechanism this interpretation is effected has not been made clear. Do the tactual centres report direct, so to speak, to the visual centres, or do both report to a higher centre, the primary visual impressions being of a crude character? Or is the correlation effected by fibres passing from one centre to the other?

In the formation of tactual representations movements play an extremely important part, and Hughlings Jackson considers that movements enter into visual representations, form and size being derived from, or representative of, motor activities, colour only being sensory; I cannot altogether follow him in this interpretation of the phenomena of vision. The dominance of the sensory side of the nervous system is not adequately recognised. I cannot argue the question out here, but I may repeat that in my opinion there is a distinction between vision as a guiding sensation for movements, and visual images as the substrata of intellectual operations, and I may add that I regard tactual impressions as being translated into visual for intellectual employment by a process which is at any rate analogous to evolution, visual images re-representing middle-level tactual impressions.

We can only obtain an insight into the mechanism of the highest level through speech, and here we have to rely entirely on the experiments performed by disease. Experiments on animals, however, while they can furnish no direct evidence with regard to the higher cerebral functions in man, afford information of the greatest value and importance. It becomes increasingly difficult when we are dealing with nervous activities, which have as their concomitants mental operations properly speaking, to avoid the use of psychical terms in a physiological sense, but it must be understood throughout that the activities of the highest level are regarded as sensori-motor processes.

I must now attempt to place before the society my own interpretation of Hughlings Jackson's theories of the construction and action of the nerve centres. I am in entire

agreement with him as to the essential nature of epilepsy, and I accept unreservedly in principle his theory of evolution and dissolution with the light it throws on insanity. But for myself I can only think of nervous action in terms of cells and fibres, and I have to endeavour to reduce the refined conceptions embodied in this theory to a cell and fibre mechanism. I must further be allowed to speak of cells and fibres and not of neurones, not only because I am more familiar with them as the structural nervous elements, but because I cannot accept all the implications bound up with the neuron theory or nomenclature.

The cells and fibres are there, and the gray substance constituted mainly of cells is the seat of nervous energy and of intercommunications, and whether the explosive material is formed in the cells or matrix, and whether the intercommunications are effected by cell processes directly or through synapses I am not concerned to discuss.

In the elucidation of the complex problems presented by the physiology and pathology of the nervous system the line of progress has always been to interpret structure by function and not to infer function from structure. To depart from this course, which is that which has been followed with such signal success by Hughlings Jackson, and to erect a theory based upon structure and to make this theory the starting-point of inferences bearing upon function is to open the door to confusion and fruitless discussion. The term neuron is a convenient expression for a cell with its processes and cylinder axis, but some of the theoretical inferences from this idea are in my opinion untenable. The individuality of the neuron, for example, seems to me to be inconsistent with what is seen in the reunion of a divided nerve, the junction of motor fibres central and distal, and of distal with central afferent fibres, we cannot suppose that each sensory and motor neuron in the proximal part of the nerve picks out its own continuation in the distal part, and yet when the recovery of sensation is complete, localisation of an impression is accurate and there is no confusion of movements. The difficulty is increased if a gap in the nerve has been filled by transplantation. Still more difficult is an explanation of the remark-

able experiment of Prof. Robt. Kennedy, related in *Proceedings Royal Society*, lxvii., p. 431. January, 1901. In the right fore-limb of a dog the central segment of the divided musculo-cutaneous, median, and ulnar nerve was united with the peripheral segment of the musculo-spiral, and *vice versa*. Recovery of function took place in about the same time as after simple division of the nerves, and the dog regained perfect use of the limb in walking and running, gave its paw when asked, and used it in holding a bone; the cortical centres were interchanged, stimulation of the extensor centre gave flexion, and of the flexor centre, extension and flexion.

In adopting Hughlings Jackson's idea of nervous representation of movements and impressions, I have considered it more accurate to speak of representation *in* the nerve centres rather than *by* the nerve centres. The representation of movements then in the spinal cord will be groups of nerve-cells arranged *ad hoc*, not the nerve nuclei of individual muscles. This important distinction as enunciated by Hughlings Jackson must always be borne in mind, but isolated movements are rare, and there exists a mechanism in this lowest centre by which the cell groups representing individual movements are associated for combined action to any required extent. The cell groups representing movements must often be very large, for example, the cell group representing a firm grasp of the hand will comprise those representing the synergic action of the extensors of the carpus. While a given movement will always be represented by the same cell group, it does not follow that these cells cannot enter into other combinations representing other movements. The same cells may be differently grouped for different movements, and the cells of one group may form part of a totally different group.

It may be assumed that sensory impressions will be represented by similar groups of nerve-cells in the posterior gray cornua. A noteworthy difference, however, exists between afferent or sensory impressions and motor efferent impulses; sensory areas overlap in the skin, and the conduction of ascending sensory currents in the spinal cord is much more diffuse than the conduction of descending currents to the anterior gray cornua.

An important preliminary question arises—how are these movement-representing cell groups formed? Many of them exist at birth, those which subserve the cardiac and respiratory reflexes for example, and such respiratory acts as sneezing, coughing, crying; those again which are employed in sucking, swallowing, and in the extraordinary prehensile grasp of the infant. But other groups representing movements are formed by a process of education as the child learns to walk and use its hands for various purposes, or as the workman learns to handle his tools. Now all movements are primarily a response to sensory impressions, and are performed under their guidance. The first nerve filaments which appear in the lowest organisms, have for their object to render the motor response to surface impressions more ready and more exact, and this response would be of no service in adjusting the organism to its environment unless it were directed by the guiding afferent impression. It is obvious that the sensory is the dominant side of the nervous system. This dominance of the sensory over the motor side of the nervous mechanism extends to the highest level of the most fully developed nervous system. It is demonstrated by such evidence as the striking and important experiment of Mott and Sherrington, the division of all the posterior nerve roots of the upper extremity in a monkey. The limb was left flaccid and helpless, the animal made no attempt to use it, and seemed unconscious of its existence.

In tabes, again, the degeneration affects the sensory or afferent side of the cord, the posterior root-zone, and the disorderly movements of the limbs are due, not to any motor paralysis, but to loss of the afferent sensory guiding impressions. These direct guiding sensory impressions can be in a measure replaced by visual guiding impressions.

The interpretation I put upon the interesting experiment of Prof. Robert Kennedy already mentioned, in which interchange took place between the flexor and extensor cortical centres both for volitional use of the limb and in response to stimulation as a result of crossed reunion of the flexor and extensor nerves, is that the sensory side of the nervous

system dominates the motor side, and that impressions on a particular sensory area determine the employment of the corresponding motor centres even in the highest level. The process would begin in the cord. The immediate effect of transposition of the divided flexor and extensor nerves would be, as reunion took place, to bring the flexor muscles into relation with the cell groups in the anterior gray cornua, which previously animated the extensors, and in like manner the afferent fibres from the flexor aspect of the limbs would be put in communication with the sensory cell groups previously receiving fibres from the extensor surface. A reflex circuit from skin to muscle would thus exist, an extensor cell and fibre mechanism being employed for a flexor reflex. This apparatus, now flexor, will be in communication with the extensor sensori-motor centre of the higher level, and a flexor response to electrical stimulation of the cortical centre is only what we should expect. What is extraordinary, however, is the re-education of the extensor cortical centre for volitional flexor use and *vice versa*; this must be through sensory impressions, and it is interesting to note that while the flexor response to stimulation of the extensor cortical centre was simple, the extensor response to stimulation of the flexor cortical centre was confused, the afferent musculo-spiral fibres being simple as compared with the afferent fibres of the musculo-cutaneous median and ulnar.

We are apt to lose sight of the fact that sensory nerve endings or beginnings must liberate energy in the act of sending an impression to the cord; there must be a discharge exactly as in the nerve centres. We see in the retina a most elaborate specialisation of nerve endings for the reception of luminous vibrations, the nerves of the skin must equally be specialised for the translation (transformation) of thermal vibrations and of contacts of various kinds into appropriate sensory impression.

The recognition of the dominance of the sensory side of the nervous system I regard as of primary importance.

The structural representation of a guiding sensory impression in the cord will be a group of sensory cells in

which the posterior nerve roots end, dominating the corresponding motor cell group with its efferent fibres, the sensory and motor cell groups being connected by processes. This is the unit of the lowest level. Simple units will be combined for the execution of movements of larger extent, as is illustrated by the extension of a reflex response as the stimulus increases in intensity. The lowest level consists of a chain of such sensori-motor units from the lower end of the cord to the nerve nuclei in the floor of the fourth ventricle united by intrinsic fibres of different lengths and connected by other fibres, which may be called extrinsic, with the centres of higher levels, and it forms a complex and efficient mechanism. How complete the lowest mechanism can be is shown by the headless frog, which rights itself when turned on its back, pushes away an irritant with its foot and, if the foot first used is cut off, will employ the other. I do not think the human cord is inferior in its essential endowments to that of the frog, and although it loses its independence by its subordination to higher centres it retains in my opinion all its potentialities.

An important item in the mechanism of the lowest level is the bi-lateral association of nerve nuclei in the case of muscles of the two sides of the body which always act together and are called into action on one side only rarely and with difficulty, if at all. In the case of bi-laterally acting muscles a commissural association of their nerve nuclei exists which renders the paralysis in hemiplegia partial and which allows movements to cross over to the sound side in hemichorea and hemispasm. It is this bi-lateral association of the nuclei of the occipito-frontalis, the levators and the orbiculars of the eyelids which prevents any obvious paralysis of these muscles in hemiplegia, while it is conspicuous round the mouth, and not any special distribution of fibres connecting the facial nucleus with the higher centres in which the lesion giving rise to hemiplegia has occurred.

In the lateral movements of the eyes and in the rotation of the head the nerve nuclei of the muscles on the two sides, which co-operate, are not on the same level; the part of the nucleus of the third which supplies the internal rectus on

one side acts with the sixth on the other ; the part of the spinal accessory supplying the sterno-mastoid on one side acts with the nerve nucleus of the opposite atlo-axoid. The commissural fibres connecting these nuclei respectively therefore, are oblique, and of a certain length instead of being transverse and so short that the two nuclei are practically fused into one. It is this which explains the temporary conjugate deviation of the eyes and head which is often observed after severe hemiplegia ; the external rectus of the paralysed side and the atlo-axoid are paralysed ; the eyes and head are acted upon by the now unopposed muscles of the sound side and turned so that the patient is looking towards his lesion. This only lasts for a few days, till the incitation, which has been intercepted by the lesion and which, reaching the sixth nucleus and the nucleus of the atlo-axoid, was normally propagated to the third and the spinal accessory, has started from the uninjured hemisphere and found its way round in the opposite direction from the third to the sixth and from the spinal accessory to the atlo-axoid nucleus. The fact that the deviation of the head and eyes occurs together and that it is fugitive makes it clear that this symptom is not due to extension of the lesion to any particular cortical centre. Here, as in the more direct bi-lateral association of nerve nuclei, the commissural fibres, which obviate paralysis by conducting the motor impulse from the uninjured hemisphere to both sides of the cord, conduct the morbid discharge to both nuclei, so that in hemispasm the conjugate deviation of the head and eyes is away from the hemisphere in which the lesion exists. There may, again, be permanent lateral deviation of the eyes in lesion of the pons implicating the commissural fibres between the sixth and third.

The bi-lateral association of nerve centres will be shown to have important applications in the higher levels. I think a further exemplification of the principle exists in the cord, in fibres which may be assumed to extend from the arm centre of one side to the leg centre of the other, or *vice versa*, which have to do with the automatic swinging of the arms in walking and running ; which may, moreover, have

to do with the imperfect paralysis of the leg in hemiplegia, and which certainly, in my opinion, give the explanation of the circus movement of the dog instead of hemiplegia in severe lesion of the motor area.

The cell groups organised for movements in the lowest level are made use of by the centres of higher levels. Indeed, to say that existing cell groups representing them in the lowest level are made use of and are brought into action in greater numbers and more varied and more purposive combinations in a higher level, is simply another way of stating that movements are re-represented in a higher level with increasing complexity, specialisation and integration.

But just as movements are represented in the cord by cell groups so will they be re-represented in the next higher level by cell groups. These must be so complicated and their inter-relations so intricate as to defy the imagination, but this is no reason for denying their existence.

Following out the same idea with regard to impressions, they will be re-represented in the next higher level by groups of sensory cells in relation, not directly with fibres of the posterior nerve roots, but with the sensory cell groups in the cord and bulb, which primarily represent impressions and guide movements, and, just as the sensory cell groups arrange and govern the motor cell groups in the cord, so must it be in higher levels, and it must be through the sensory cell groups that the complex motor cell groups are arranged for their duties.

But interposed between the lowest and next level, or superposed upon the point of junction is the cerebellum, which, from its size and extensive relations, must play an important part in the mechanism by which the higher level makes use of the lower. It is connected by its inferior peduncle with the cord, with the central ganglia and cerebrum by the superior peduncle, but the middle peduncle is much larger than the superior and inferior put together and its fibres decussate in the pons, interlacing with the longitudinal fibres of the cerebro-spinal axis and ending in the cells of the gray matter which occupies the interstices between the transverse and longitudinal fibres and no doubt connect them. Both experiment and disease show that each hemi-

sphere of the cerebellum is functionally associated with the opposite cerebral hemisphere and the same side of the cord.

Now, we know that the cerebellum has nothing to do with the initiation of purposive movements of the limbs or with the sensory cell groups which govern them. There is practically left to it only functions which will come into operation in subordination to the cerebrum. One view is that it specially coördinates the movements of locomotion. In my opinion this is a very imperfect conception of the part played by the cerebellum. It is the seat of the elaborate coördinations which are demanded by every movement of both upper and lower limbs. This may be illustrated by an example. A man strikes a blow; the cerebral purposive part of the action is the clenching of the fist and the shooting out of the arm in a definite direction. But the act, to be effective, demands the co-operation of every muscle of the body, the trunk becomes rigid and is thrown powerfully forward, the legs are firmly planted and spring to the effort. This is what is done by the cerebellum. Such an interpretation of its action falls in with Hughlings Jackson's opinion that the cerebellum is mainly concerned with movements of the body as distinguished from the limbs. The trunk muscles must co-operate in every action of the upper limbs as well as in the balancing of the body in station and locomotion in which the lower limbs are engaged.

Hughlings Jackson has observed cases in which tumour of the middle lobe of the cerebellum has given rise to tetanic rigidity of the spine, and he instances a most instructive contrast between the phenomena of Jacksonian cortical convulsions and this condition. In the one, movements unilateral, beginning in the hand, spreading upwards, clonic; in the other, bilateral, as are the usual movements of the trunk, invading the limbs downwards, tonic in character. The unopposed cerebellar influence to which Hughlings Jackson attributes rigidity and exaggerated kneejerks is another name for the mutual tension which exists between one centre and another.

Where, then, is the first of the higher levels? In this lecture I have followed Hughlings Jackson in speaking of it

as constituted by the corpus striatum and the Rolandic gyri, but the view that I have held has been a very old one—that it was constituted by the thalamus and corpus striatum so that I make four levels, and, while I acknowledge that the evidence of Wallerian degeneration appears to be altogether against me, I am not yet entirely convinced that these ganglia do not constitute a sensori-motor level.

My conception of the relation between the different levels does not admit of continuous fibres from the motor area of the cortex to the anterior gray cornua or of afferent fibres unbroken by cell-network from cord to cortex, whether from the point of view of a mechanism competent for the complicated relations involved, or from the point of view of evolution. It is incompatible, indeed, with re-representation.

If the degeneration seen in the pyramidal tracts after a cortical lesion in the Rolandic region is absolute proof of continuity of the fibres without interruption by cells or communication with cells by branching in the corpus striatum, this view can scarcely be sustained. But if fibres of the corpus callosum are reached by degeneration in advanced stages of lateral sclerosis of the cord, as described by Mott in a recent paper in *BRAIN*, it is clear that cells do not constitute a barrier to secondary degenerative processes. I do not propose to argue the question, but these great masses of gray matter, by far the largest aggregation of cells which are to be found in the nerve centres, and which seem to form a distinct and natural link between the cord and brain, are apparently left without function. I cannot believe that experiment has said the last word with regard to them and there comes to mind Hughlings Jackson's repeated and emphatic contention that discharge may give rise to movements, when destruction or removal does not produce paralysis, and that the experiments performed by disease may disclose nervous mechanism and function. At one time when hæmorrhage gave rise to hemiplegia the lesion was described as being in the corpus striatum, but the corpus striatum is now deposed in favour of the internal capsule. The internal capsule, however, belongs in great part to the

corpus striatum and thalamus and is largely made up of fibres arising in the cells of the central ganglia and passing between them and the convolutions. The central ganglia seem to me to be singularly suitable as the seat of the complex cell groups, sensory and motor, just considered, and that they must play some extremely important part in the mechanism of the nerve centres is shown by the enormous accretion which they contribute to the fibres ascending from the cord and bulb to the cerebral hemispheres.

Before going further I must devote a short time to the conclusions at which I arrived in an endeavour to trace the course and destination of the fibres which ascend from the cord to the brain, and to obtain an idea of the structural arrangements of the hemispheres.

To this task I devoted two years, and, while I am the first to acknowledge the limitations of the method I employed, which was to follow the fibres in the spirit-hardened brain, I can speak with confidence of such results as I obtained.

Beginning with the *crus cerebri* we have in it for the first time a separation between the sensory and motor tracts, the *pes* or *crusta*, motor, the *tegmentum*, sensory. In both there are many more fibres than can ascend from the lowest level, including, of course, among these not only the continuation of the cord, but also the crossed fibres from the nerve nuclei in the floor of the fourth ventricle and fibres ascending from the *corpora quadrigemina* and optic tracts. The additional fibres are contributed by the *cerebellum*, directly by the superior peduncles, which merge in the *tegmentum*; indirectly from the gray substance in the interstices of the decussation of the middle *crura*, which apparently form part of the *crusta*. The red nucleus in the *tegmentum* corresponds with the olive in the medulla, and belongs to the cerebellar mechanism.

Following the composite tracts upwards they expand fanwise, the fibres diverging rapidly, and there is a gentle rotation of the plane so that the borders of the two fans become approximately anterior and posterior,

the internal tegmental surface, which is convex, looking upwards, the external, slightly concave, surface looking downwards. Anteriorly, the internal fan overlaps the external and curls round it towards the anterior perforated space in such a way, that Gratiolet speaks of "la partie perforante" and "la partie perforée." If we may be allowed to speak of the caudate body and the lenticular body as component parts of the corpus striatum, the corpus striatum may be said to sit astride of the anterior border of the double fan, while the thalamus, resting on the inner fan below the caudate nucleus, curves round the posterior border, narrowing down into a sort of tail, which forms the collar of the peduncle along the course of the descending cornu of the lateral ventricle. The double fan-like expansion of the crus just described is what has been called the internal capsule, because in its concavity lies the lenticular nucleus. This name is singularly inappropriate, and under the disguise which it affords, the multiple source of the fibres and their afferent, as well as efferent course, escape attention. A better name would be the central expansion of the peduncle. It is here that cerebral hæmorrhage most frequently occurs, and it is to rupture of its fibres by the extravasation that the paralysis is attributed, but there must also be damage to the gray substance lying between the white striations, *i.e.*, to the corpus striatum, and extensive disruption of cell and fibre connections.

What proportion of the fibres, crustal, or tegmental, or cerebellar, continue upwards to the convolutions, what proportion end in the central ganglia, what part is taken by the masses of cells in the thalamus and corpus striatum in the relations between the cord and the hemisphere, is not definitely known. It is, however, certain that great numbers of fibres, afferent and efferent, arise in the central ganglia and pass with the diverging crural fibres to the corona radiata. Large bundles can be seen in the spirit-hardened hemisphere to pass upwards and forwards from the thalamus; the external capsule is formed by fibres which arise from the gray matter of the lenticular nucleus and pass

upwards to the corona radiata as it emerges from between the central ganglia, intersecting its fibres at an acute angle ; it is less easy to trace fibres from the caudate nucleus, but they are evidently very numerous. Before the radiating fibres of the two fan-like expansions, at first quite distinct, emerge from between the central ganglia they have become commingled, and a great interlacement of fibres takes place. They are now re-named and become the corona radiata. In the corona radiata it is no longer possible to distinguish between the fibres having different origins, but, while crusta-corpus striatum fibres predominate anteriorly, and tegmento-thalamus fibres posteriorly, it appeared to me that, for the most part, if not entirely they were distributed together, and I could assert with absolute confidence that they passed only to what may be called marginal convolutions—the upper border of the hemisphere, the frontal extremity and the occipital tip, the convolutions around the sylvian, parieto-occipital and calcarine fissures, the gyrus hippocampi and the two great Rolandic gyri. Large areas of convolutions remain which receive no radiating fibres whatever, and these are the very convolutions which are interposed between the simple marginal convolutions of the lower monkeys to constitute the difference between their brain and the brain of man.

Flechsig, by the method of tracing the order of myelination of fibres in the nerve centres of the foetus, which he originated and has followed out with such interesting results, has more recently reached the same conclusion that considerable areas of convolutions in the cerebral hemispheres are what he calls centres of association, receiving no projection or radiating fibres, and these correspond in great measure with those which I indicated. I may point out, however, that the radiating projection fibres have various sources and in particular that they are efferent as well as afferent. Efferent functional activity will be a necessary consequence of the functional activity of afferent fibres, and of the cortical gray centres, to which they pass, and the fitness for this will involve myelination. A better name for these sensory projection centres, all of which are marginal,

would, therefore, be sensori-motor. The bodily sensibility projection centre, however, as indicated by Flechsig, encroaches upon a part of the inner flat surface of the hemisphere which I found to belong to the longitudinal commissural system of this aspect, fibres arising in the gray matter of the gyri curving downwards and then forwards and running parallel to the corpus callosum.

A further interesting fact is that the fibres of the corpus callosum are distributed to the same convolutions as the radiating fibres, though in very different proportions, and that they connect throughout, the corresponding parts of the two hemispheres, thus constituting a bilateral association. The most abundant distribution of callosal fibres is along the great longitudinal convolution, which receives comparatively few radiating fibres and apparently only in certain parts, while the number going to the Rolandic convolutions seems to be small.

It is probable that fibres of the corpus callosum bend down to form a commissure between the central ganglia; it has, indeed, been asserted that this was its entire object.

When we examine the structure of the individual convolutions, we find that fibres arising in the gray matter of the sides of the sulcus up to the free surface of the convolution curve very obliquely under the bottom of the sulcus to the gray matter of the adjacent gyrus. Some of the convolutions are entirely exhausted by such fibres. In most, a thin plane of fibres remains along the axis of the convolutions, arising from the gray substance at its summit. This axial plane is thickest in the prefrontal convolutions, which are themselves comparatively small, and here also the arrangement of the fibres is most intricate. It is only the summit of the gyrus which receives radiating fibres or fibres associating it with distant convolutions. The association or convolution commissural fibres mostly take a longitudinal direction. In the posterior part of the hemisphere fibres can be seen to curve forwards to form a large mass in the long axis of the hemisphere, which can be followed as far as the posterior Rolandic gyrus. Here they intersect the radiating fibres, and probably many turn aside with

them to end in the Rolandic convolution, but masses of fibres can be seen to emerge in front of the anterior Rolandic gyrus, to be distributed to the frontal convolutions. Along the inner flat surface of the hemisphere is another system of longitudinal fibres, from the parieto-occipital fissure forwards. A smaller system runs in the depth of the Sylvian fissure.

Since the corpus callosum, while connecting symmetrically convolutions in the two hemispheres which receive radiating fibres, is predominantly distributed to the great longitudinal convolution which receives comparatively few, and apparently very little to the Rolandic area, in which so many radiating fibres begin or end, it is probable that it is largely a commissure of the highest level.

LANGUAGE.

The functional activities of the highest evolutionary level are not open to experimental investigation, and we have to rely on the experiments performed by disease for our knowledge of their physiology and pathology. The most characteristic manifestation of these activities is speech, and it is by study of the affections of speech that a clue is obtained to the mechanism underlying the intellectual operations properly speaking.

Hughlings Jackson has not given us any complete theory of language, but I am not sure that he has not done more towards the elucidation of the problem of speech than those of us who have attempted its solution systematically. He has, at any rate, laid a solid foundation for enquiry and cleared the path of investigation by his fundamental analysis of language, the division of speech into intellectual expression and emotional expression, including in the first pantomime, in the second gesticulation. The unit of intellectual expression is a proposition, the third left frontal convolution being the way out for intellectual expression. There is no such thing as a faculty of language. Language, like all nervous operations, consists in the coördination of impressions and movements and is a sensori-motor process. Intellectual

expression, when followed to its source, merges in the larger term of special movements acquired by the individual; emotional expression consists of inherited movements and is automatic.

This fundamental distinction between intellectual and emotional expression enables us to understand how a man otherwise speechless can give vent to oaths and exclamations, may be surprised into saying "How do you do?" or "Good-bye," can often say "Yes" and "No," the articulation in all these cases being distinct. The threefold employment of the word "No" is instructive; it may be an emotional expression, or an intellectual negative, or an imitative articulation, and cases are not uncommon in which an aphasic patient will answer "No" appropriately and unhesitatingly who cannot repeat the word when asked to do so; in one instance which I have recorded, the patient, after great effort to repeat "No" after me, would give it up with a negative shake of the head, saying "No, I can't."

The views I entertain on the mechanism of speech and thought have been set forth in papers contributed to the *Medico-Chirurgical Transactions*.¹

Words as movements, like all other movements, are represented in the nervous centres by motor cell groups, and these motor word cell groups will, like all other motor cell groups, be arranged and guided by sensory cell groups, which will in the case of words be auditory. Now words may be merely imitative, may have no symbolic significance, as in the words spoken by a parrot or taught to a child, irrespective of their meaning, or belonging to an unknown tongue. An articulate sound as heard is represented by a given arrangement or grouping of receptive cells in the auditory sense centre; it is imitated or reproduced vocally by a corresponding definite arrangement and combination or grouping of cells in a motor centre, which is effected under the guidance of the auditory cell groups. The motor group when formed calls into action the appropriate motor nerve nuclei concerned in articulation.

¹ Vol. lv., 1872; lxi., 1878; lxxvii., 1884.

An articulate sound may further, by association, be made to indicate an external object without rising to the dignity of an intellectual symbol, as when a dog or an infant knows which member of the family is designated by his or her name. There is here a simple association of a visual and an auditory impression.

It will be convenient to consider here the extension of the principle of the bilateral association of nerve nuclei to the higher centres. It leads by an independent and quite different line of argument to the conclusion in which Hughlings Jackson thought he stood alone, that words are represented in the right as well as in the left hemisphere. The principle, it will be remembered, is that when muscles on the two sides of the body always act together, their nuclei situate in opposite sides of the cord are so closely associated by commissural fibres as to be practically one nucleus. Now in speech all the muscles employed are bilaterally associated. In phonation the bilateral association of the laryngeal muscles is absolute, and while the two sides of the tongue and lips are capable of independent action they always act together in articulation. There must therefore be motor cell groups representing words in each half of the bulb, and they will be symmetrical and bilaterally associated.

Not only have we bilateral association of motor nerve nuclei for articulation in the bulb, but, while there is no bilateral association of sensory nerve nuclei in the cord, when we come to hearing and vision the sensory impressions from the two ears and two eyes are, so to speak, fused; there is complete bilateral association.

Now just as the cell groups representing given movements in the cord are arranged by corresponding cell groups, so the cell groups for words will be arranged under the guidance of auditory impressions. At a higher level, again, the motor centre for imitative articulation will be educated by the auditory perceptive centre. But hearing, being bilateral, the auditory perceptive centres on the two sides will be bilaterally associated, and it must follow that the motor centre for imitative articulation is educated in each hemisphere. A further conclusion which seems to me

to be inevitable is that the right third frontal convolution is educated for utterance as well as the left. Motor cell groups for words will be organised in both. It is, of course, difficult to reconcile with this view the specialisation of the third frontal of the left hemisphere only for speech, but this difficulty exists whatever our theory of speech may be, and the employment of one side only of the brain in intellectual expression can never cease to be a matter of astonishment.

The explanation is Moxon's hypothesis that the left hemisphere is predominantly employed in the most voluntary of all movements of the limbs, those of the right hand, and that this has led to the education of the hemisphere for language, which is the highest and most complex of voluntary movements.

The view that verbal cell groups are formed in the right third frontal gyrus endows with special interest the part of the corpus callosum which unites the two third frontal gyri. In my opinion, it is by the commissural fibres crossing from one to the other that aphasia is escaped when the descending fibres from the left third frontal are torn across by a hæmorrhage in the internal capsule. The gray matter not being damaged, speech, organised in Broca's convolution for transmission downwards, crosses over to the right third frontal, where, as has been said, motor word groups already exist, and in this way reaches the bilaterally associated nerve nuclei in the bulb. A certain delay may be required for the establishment of this roundabout route. If in a case of right hemiplegia without aphasia the anterior part of the corpus callosum were divided, aphasia would follow.

The curious mirror writing sometimes seen in right hemiplegia without aphasia seems to afford strong confirmation of the organisation of word groups in the right hemisphere. The right hand being paralysed the patient cannot write. He at once, however, proceeds to write with the left, currently and without practice, but in the opposite direction across the page and apparently illegibly till the script is held before a mirror, when it is seen to be the patient's normal handwriting. The only explanation of this extraordinary accomplishment which seems possible to me is

that concurrently with the education of the graphic motor centre in the left Rolandic area there has been an unconscious imitative education of a corresponding centre in the right hemisphere, which could only be effected through the commissural corpus callosum fibres connecting the two.

Before the employment of words as symbols can be followed I must enter upon a brief explanation of my view of the evolution of ideas, and of the nervous mechanism concerned in it.

As impressions ascend from one evolutionary level to another and from being represented are re-represented and re-re-represented, we have not only the increasing number, complexity, and indefiniteness of these inter-relations, but what may be called an intellectual elaboration. In the infant, while the upward paths in the hemisphere are still undifferentiated, the concomitant state of consciousness will not rise higher than crude sensations of light, sound, contact. A step higher is perception, which for my present purpose I define as the recognition of the external cause of any sensation. The seat of this elaboration I believe to be those of the marginal and post Rolandic convolutions, to which are distributed afferent sensory radiating fibres. They will constitute the visual, auditory, olfactory, gustative and tactual perceptive centres. Each of them will educate its corresponding motor centre. The senses of smell and taste may be dismissed as having practically no intellectual associations, though odours have curious emotional relations. The tactual perceptive centre will organise all purposive actions, especially the varied and delicate purposive movements of the hands; the visual perceptive centre will take part in this intellectual education of the hands and other parts, inasmuch as the movements, though organised tactually, are, for the most part, employed under the guidance of vision. It is argued (Spencer) that "tactual impressions are those into which all other impressions have to be translated before their meanings can be known." Accepting this as true, it is in visual perceptions thus verified that mentation is, for the most part, carried on. Visual ideas stand on a higher intellectual plane than tactual

impressions ; they re-represent them and are, in a sense, symbols.

The auditory perceptive centre will educate the third frontal convolution, will direct the formation in this gyrus of word groups, which no longer represent simply imitative articulate sounds, but sequences of words as employed in language. Articulation is not affected in lesions of this centre. We have loss of speech or mistakes in words.

Even now, however, we have only reached a rudimentary stage of intellectual evolution. We have to consider the formation of ideas and their embodiment in words ; the employment of words on the one hand as symbols representing elaborated sensory impressions, and on the other as expressive of intellectual motor activities. For Hughlings Jackson, the idea of an external object is a faint image of a previous sensation, and is concomitant with a faint reproduction of the activities in the same cell and fibres, which, when strongly excited, were the anatomical substratum of the sensation excited by the object ; the very same cells and fibres which are brought into activity when a sensation of any kind is experienced or an action performed, are engaged in its reproduction in memory. This may be accepted as far as it goes, but the idea, say of an orange, is compounded of several perceptions, colour, form, size, feel, fragrance, taste. It seems to me that we have here a further intellectual elaboration, and that its seat and substratum will be some part of the superadded convolutions. My hypothetical interpretation of the process is that impressions are transmitted from each perceptive centre to a higher cortical centre, where they are coördinated into a complete idea or mental picture of the object. But all these qualities, if we may use the term, or perceptions are suggested or brought into consciousness by the name, that is, a further association is effected in this centre with the name—an arbitrary auditory symbol, which has no relation whatever to any property of the object, but which thenceforward represents it in consciousness. The act of naming, of symbolising by a word, marks an enormous intellectual step, and is the basis of all mental operations. The cortical area, in which the coördina-

tion of the various perceptions and the associations with a name takes place, I have called the naming centre. Another name for it would be the idea centre.

The assumption that such a centre exists and is the starting-point for further intellectual operations, seems to me to be the simplest and indeed the only explanation which my imagination can grasp of the different forms of sensory aphasia. One of these forms is the so-called word-blindness, a case of which I related in the *Medico-Chirurgical Transactions* for 1872, vol. lv.

In this case, however, as in every case which I have personally seen, the word-blindness was only a part of a much wider defect, and applied to such a case the term "word-blindness" lacks precision and is altogether misleading. It was not only that the patient did not recognise printed or written words, even when he had written them himself, but he could not name any object whatever at sight. If a wrong name were suggested, however, he would dissent, and would eagerly point to the object to which the name belonged.

Here the path from the visual perceptive centre to the naming centre had been destroyed. I will not venture to say that the loss of the power to name things at sight is present in all cases of word-blindness, but it is often overlooked. On several occasions when I have been asked to see a case of word-blindness, this wider defect had not been suspected until the test has been applied at my suggestion.

A more complicated form of sensory aphasia is word-deafness, when the path between the auditory perceptive centre and the naming centre has been divided. Here the confusion is much greater. The patient cannot understand what is said to him, and he may or may not know what he himself says.

In other forms, the naming centre itself appears to be destroyed.

I have recorded cases exemplifying each of these lesions.¹

Carrying out the idea of sensori-motor processes, the correlative of the naming centre will be a propositionising centre, which I take to have its seat in the prefrontal con-

¹ *Medico-Chirurgical Transactions*, lxi.

volution. This has subordinate to it the two chief ways out for intellectual expression, speech and writing, the articulatory and the graphic. Speech and writing are commonly lost together, and since writing is a later acquisition than speech and is learnt through speech, it was natural to conclude that, in a sense, writing was only a subordinate form of articulate language, and could never be so far independent of it as to be a vehicle for intellectual expression when speech was lost. Examples are, however, on record, and more than once I have seen writing recovered before speech, when both have been lost. This seems to me to imply the existence of a centre which employs both the graphic centre and the way out for spoken words. It is above both and forms the propositions which are transmitted to them for expression. Moreover, educated and intelligent patients, capable of understanding the question, have told me after their recovery, that while speechless, they not only knew what they wanted, but could mentally rehearse the words and phrases which expressed their wishes.

Between the naming centre and its propositionising centre will be fibres, which I believe to be the fibres which pass forward in the axis of the hemisphere from the occipital to the frontal convolutions.

The only parts of speech with which the naming centre will be concerned are nouns, which are the sensory elements of language, together with pronouns and adjectives. All other parts of speech are motor, and these the propositionising centres will supply. I have reported two cases which appear to me to exemplify division of the fibres, connecting the naming and propositionising centres. The patients had completely lost nouns. One of them I saw from time to time and had long conversations with, and for two years he was under the observation of an educated and intelligent nurse and of relatives, who were instructed to be on the look out for nouns in his speech, and were competent to distinguish them. During these two years, while he could say any other words and could communicate his wishes by words and signs, he never said a noun. In the other

instance, I sat by the bedside of a lady who was talking volubly all the time for twenty or thirty minutes, during which she did not utter a single noun, except adverbially. The name or noun centre could not supply nouns to the motor propositionising centre, which was itself in good working order.

On the other hand, in a case reported by Professor Oliver, of Newcastle-on-Tyne, *British Medical Journal*, July 11, 1903, the patient could not put a sentence together, she "could supply all the nouns and many adjectives, but could not put in the verb." The motor side of the propositionising sensori-motor mechanism was damaged. Cases such as this are very uncommon, but it may be because the prefrontal convolutions are so rarely the seat of disease.

In association with the naming centre, which will be somewhere in the posterior part of the hemisphere, will be the convolutions, which are the seat of the nervous activities corresponding to the forming of abstract conceptions, the comparison, ordering and association of ideas, the play of the imagination, which constitute the exercise of the intellectual faculties. These are essentially sensory operations; some of us think mainly in visual images, some mainly in verbal symbols, and the thinking goes on without seeking outward expression. The correlative highest motor mental faculties will have as their instrument the prefrontal convolutions, which will be reached by commissural fibres from the sensory convolutions lying behind the Rolandic gyri.

Innumerable questions present themselves for discussion when the mechanism of speech and thought are under consideration, but there is only one which is of sufficient importance to be alluded to in this lecture. It is the remarkable fact that many aphasics can utter numerals—can count from 1 to 20 when they cannot recite even a fragment of the alphabet—can tell accurately the number of coins shown to them—in one case the numeral would carry with it the name of the coin "five shillings"—can answer questions relating to numbers—can even write figures if not paralysed. There is nothing emotional about arithmetic

and accurate enumeration is not automatic. We cannot fall back on either emotional expressions or automatism as an explanation. To state a number might almost be called *propositive*. It is possible that the explanation lies in the fact that number is an *abstract conception* of a quite special kind, which, though formed by enumeration of external objects, becomes independent of them, ceasing to have any relation with visual or other sensory impressions proper, and that the right hemisphere is concerned in this mental operation.

There are interpretations of the physiology of speech in which I cannot follow Hughlings Jackson. He speaks of the left as the leading hemisphere, which is indisputable, and of the right as more automatic, which is probably true, suggesting that in motor aphasia, when the patient while speechless is not wordless since he understands what is said to him, the words are revived in the posterior part of the right hemisphere, and that such recognition of words is automatic because it is in a sense involuntary. I cannot regard the comprehension of spoken words as automatic; it is an acquisition by the individual, as speech itself is, and that the right hemisphere is not concerned in the recognition of language, spoken or written, is shown by the so-called word-deafness and word-blindness, which can be induced by lesion in the posterior part of the left hemisphere.

I am unable again to regard words when employed in thought, especially words expressing abstract ideas, as revived articulatory movements or to consider that motor aphasia is adequately explained as being the loss of articulatory motor processes. It is no doubt true that mental states attend the energising of motor as well as sensory processes, of outgoing as well as incoming currents, but in my judgment words in mentation are sensory symbols; their significance as such is learnt before utterance is acquired.

While I agree with Hughlings Jackson that all parts of the body are re-re-represented in the highest centres, all afferent impressions from sentient surfaces, muscles and viscera, and all movements, skeletal, visceral, vascular,

secretory, and thermal, which are excited by efferent impulses, I do not go with him in his view that each unit in the highest level represents all movements and all impressions, certain impressions or movements specially and particularly, others generally and slightly. As a cell and fibre mechanism this conception raises difficulties which are insuperable.

Certain facts which he thinks cannot be explained on any other hypothesis than universal representation—why in hemiplegia the hand, with its fine purposive movements, always suffers most, and hemispasm of cortical origin always begins in the hand; how compensation with recovery of some degree of function can be effected after destruction of a cortical motor centre if the movements are not represented in other parts of the cortex, are, it seems to me, easily understood on his own exposition of evolution and dissolution. It is only in the highest level that the most purposive movements are represented and it follows that in destruction or discharge of highest level centres they will be the most affected while more automatic movements of the upper limb are represented in lower levels and will be less affected. So, again, a certain degree of compensation may be effected by readjustment of cell groups in the lower levels.

I agree also with Franck and Pitres that convulsions started by a discharge in a limited area of the cortex may be generalised by the lower centres.

It will be understood, I hope, that in these remarks I speak as a disciple not as a critic.

There is no finality in nervous physiology and pathology any more than in other branches of knowledge but it is my unwavering conviction that, whatever further advance is made, the work of Hughlings Jackson will always form one of the corner stones of neurological science. It belongs to the highest evolutionary level of the neurology of the present day and the ideas found in his numerous writings will be important factors in any fuller comprehension of nervous action and function which may be hereafter attained.

The theories of his, which I have brought once more before the Society, are no fantastic hypotheses, having no point of contact with nature or practical application to our work as medical men. They have been projections of the scientific imagination into the unseen, such as are always necessary to the marking out of the pathway for the advancement of knowledge. From their very nature they have conduced to precision as well as minuteness of observation. They have given point and direction to clinical work and so rendered it more valuable, and have inspired and guided investigation

Were they swept away, which, for my part, I do not believe will ever be the case, it would still be emphatically true that Hughlings Jackson has been a pioneer in nervous physiology and pathology.

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