An attempt to remove the difficulties attending the applications of Dr. Carpenter's theory of the function of the sensori-motor ganglia to the common form of hemiplegia / by W. H. Broadbent, M.D.

An attempt to remove the Difficulties attending the Application of Dr. Carpenter's Theory of the Function of the Sensori-Motor Ganglia to the Common Form of Hemiplegia.

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An Attempt to remove the Difficulties attending the application of Dr. Carpenter's Theory of the Function of the Sensori-motor Ganglia to the common form of Hemiplegia.

This theory, as is well known, is, that the thalamus is the organ of conscious sensibility, to which all impressions made on peripheral sensory nerve-fibres must be transmitted in order to be recognised as sensations, and the corpus striatum the organ or instrument of voluntary motion,—the downward starting point of volitional motor impulses, or it might be said of all cerebal motor impulses. These two ganglia are again associated according to the theory of Dr. Carpenter in sensori-motor action, impressions reaching the thalamus being passed on to the corpus striatum, and giving rise to automatic movements differing from those which have their centre in the cord, only in being accompanied by sensation.

The common form of hemiplegia is caused by hæmorrhage, or softening in one or both of these bodies on one side, and the difficulties presented are: that the thalamus and corpus striatum being considered respectively the organ of sensation and motion of the opposite half of the body, the motor paralysis is not general in that half, but affects only the limbs, tongue, and face, while sensation either escapes altogether or is only partially lost. These difficulties have hitherto prevented the theory from obtaining general acceptance.

As different interpretations of the results of experimental and microscopic investigations of the spinal cord and medulla oblongata have been given by different physiologists, it is necessary to state briefly the views I hold as to the function and mechanism of these parts.

The gray matter of the cord then I look upon as containing a series of sensory and motor nerve-nuclei connected together trans-

versely, and fused longitudinally into a continuous chain. With the posterior and anterior nerve-roots they constitute an apparatus for automatic or reflex action. From the sensory nerve-nuclei communications pass upwards in the gray matter to the thalamus, these crossing in the cord; to the motor nuclei, fibres descend in the antero-lateral white columns from the corpus striatum, decussating at the point of the medulla. The posterior white columns are longitudinal commissures between the superimposed nuclei for co-ordinated movements.

The medulla oblongata is simply a more highly specialised portion of the cord, but has in addition to sensory and motor nerve-nuclei certain accessory ganglia. The constituents are also re-arranged. The nerves given off from it having special local distribution and functions of great importance, the nuclei are large, and distinct one from another. The reflex actions also which have their centres here, involve the co-ordinated action of an extraordinary number of muscles, and are of the highest importance to life; the provision for this co-operation by means of commissural fibres must be of corresponding extent. But this localisation, or individualisation of nerve-nuclei, and linking together of sensory and motor nuclei confers upon them no new property. Voluntary motion does not originate in a motor nerve-nucleus of the medulla, and sensation is not recognized as such by a sensory nerve-nucleus. Each is connected with the corresponding sensory or motor ganglion, thalamus or corpus striatum, just as are the nerve-nuclei of the cord, the communicating fibres crossing the septum, and ascending in the opposite half of the medulla and pons.

These remarks may also be applied to the pons, so far as concerns nerve-nuclei and the longitudinal tracts of fibres.

The thalamus being thus looked upon as the seat of sensation, and the corpus striatum as the instrument of volitional (ideational) action; the pons, medulla, and cord, being considered merely as subsidiary mechanism, the questions arise in hemiplegia, caused by injury to one or both of these bodies:

1. Why is not sensation more frequently and profoundly affected?

2. Why is not the entire half of the body, head, and neck paralysed as to voluntary motion, instead of merely the limbs, and in a partial degree the face and tongue?

The first of these questions has recently been put forward prominently by Dr. Hughlings Jackson, in vol. ii. of the 'London

Hospital Reports,' as one of the discrepancies between what he terms "medical" physiology and "school" physiology. He exaggerates the discrepancy, however, for he says, "As a rule, there is no loss of sensation anywhere." In opposition to this assertion, I might quote any number of authorities, and I can state from my own observation that sensation is very frequently diminished, sometimes very greatly. I have tested it by pricking and pinching, by the compasses, and occasionally by hot substances, the sound side being always used as a point of comparison. This does away with the idea that a subjective complaint of "numbness" has been set down as a loss of sensation. Moreover, it is not the sensibility of the limbs merely, where the motor paralysis is most marked, which is affected, but also of the face, chest, and abdomen.*

It is a fact, however, that in common hemiplegia sensation is never (so far as I know) totally lost, and that it is often altogether unaffected when the motor paralysis is complete, and this requires explanation. First, how is it that sensation so frequently escapes when motor power is lost, while the converse never occurs?

A reason for this, almost in itself sufficient, is found in the relative situation of the two bodies. The corpus striatum, the motor ganglion, is in front of, and external to the thalamus, and may be extensively damaged without involving the thalamus or the fibres passing from it to the cord. The thalamus, on the other hand, lying behind the corpus striatum, and upon the fibres connecting it with the cord, can scarcely be seriously affected without injury to these fibres or the corpus striatum itself.

Again, the thalamus, according to hypothesis, standing with respect to the corpus striatum in the relation of a sensory to a motor nerve-nucleus, it would almost follow that severe injury to the former would paralyse the latter by inhibitory influence, even when the injury was confined to the thalamus, and did not reach the corpus striatum directly or indirectly.

It still remains to be explained, however, why the loss of sensation is not as complete in degree when the thalamus is the seat of softening or hæmorrhage, as the loss of motor power in the limbs when the corpus striatum is affected.

A parallel is furnished by disease of the spinal cord, motion

* I ought to add that my observations have mostly been made on recent cases, Dr. Jackson's on old cases, and that sensation is recovered more rapidly than motion.

being almost always first and most profoundly affected, and both are explained by Dr. Brown-Séquard's experiments on the cord. He found a remarkable difference in the results of section of the white motor columns, and of the gray matter along which the sensory impressions travel. The cutting across of a group of fibres in the motor tract was followed by a certain appreciable muscular paralysis, but considerable injury might be done to the gray matter before any loss of sensation became apparent, and while a single slender bridge of gray substance remained a considerable degree of sensibility persisted in the whole of that part of the body behind the seat of the injury. The entire sensory tract resembles in structure this gray matter of the cord, and the thalamus itself instead of presenting like the corpus striatum distinct gray matter with white fibres plunging into it, consists of an intimate admixture of cells and fibres. Without pretending to explain this diffused transmission of sensory impressions along the cord, we may fairly suppose it to prevail in the higher part of the sensory tract, and to be shared by the thalamus. If this be admitted, it is clear that only such an amount of destructive change, as should leave no fragment of this body in relation with the sensory tract, would produce complete anæsthesia. We should, in fact, expect that injury to the thalamus would manifest itself rather in inhibitory paralysis of the corpus striatum than in marked loss of sensibility.

I have left out of this consideration the special senses, recognising, however, that their exemption constitutes a grave difficulty. If their nuclei, say of the gustatory or auditory, are centres of sensation independently of the thalamus, there is no reason why that of the trigeminus should not have the same property, which would be fatal to the theory of the office of the thalamus. If on the other hand, these nuclei are supposed to stand in the same relation to the thalamus as the sensory nuclei of the cord, the exemption of the special senses requires special explanation. This, I believe, may be given, but it will better form the subject of a separate communication, and the difficulty must be left where it stands.

Many physiologists locate sensation in the medulla or pons. Some even suppose, that all the sensory nerve-nuclei of the cord are centres of sensation. These hypotheses would explain the absence of any impairment of sensibility in hemiplegia, but the loss of sensation often met with would furnish a greater difficulty than the one escaped from. I cannot now go into the objections

which might be urged against these views, but pass on to the question respecting motor paralysis.

The difficulty here, as has before been stated, is, that the limbs, and in a less degree the face and tongue, only are paralysed, and not the entire lateral half of the body.

In attempting an explanation of this, it becomes necessary to specify the muscles paralysed, and more particularly to determine the precise character of the facial paralysis in hemiplegia. The contrast between facial paralysis proper and facial hemiplegia has been frequently described. Dr. Todd accounted for the differences observed in the two instances, by supposing that in hemiplegia the motor division of the fifth was affected, the seventh escaping, but this view, I suppose, is not now held by any one who has given attention to diseases of the nervous system. The distortion of facial hemiplegia, as in facial paralysis, is generally recognised as being due to paralysis of the seventh nerve, but as to the exact character and extent of this paralysis there is still diversity of opinion. Dr. Hughlings Jackson, in the paper before referred to, says, "the paralysis is simply of a small part of the face near the angle of the mouth,—not of the portio dura, but of part of it." It is true, that the paralysis is most evident in the part of the face referred to, but no muscle supplied by the portio dura altogether escapes paralysis, while, on the other hand, the paralysis is complete in none of them. It is not necessary to describe the expressionless condition of the affected side of the face, or the partial obliteration of the muscular markings; but it is important to observe that this extends in a slight degree to the forehead, where the wrinkles in a recent and severe case when well marked, will be found slightly smoothed out, and the vertical furrow produced by the corrugator supercilii a little less deep. The orbicularis oculi which furnishes the most striking point of contrast between "facial paralysis" and "facial hemiplegia," itself gives evidence of impaired power. For a short time after a severe attack, it is obviously weakened, and this may be rendered more evident by bidding the patient close both eyes powerfully, or again, by asking him to wink the eyes alternately. The eye on the hemiplegic side cannot be closed alone, and the voluntary contraction of the orbicularis of this side will be seen to be less forcible. On the other hand, it is equally important to note, that in the region about the angle of the mouth where the paralysis is most marked it is not complete. The dragging over of the mouth to the sound

side is not so great as in paralysis of the portio dura, and imperfect movements may be observed in the paralysed muscles. All the facial muscles, therefore, are partially paralysed, though in very different degrees, none completely so. I should place them in the following order. Least of all the small muscles of the alæ nasi, the orbicularis oculi, the occipito-frontalis, and corrugator supercilii; next, at a long interval, the orbicularis oris; most of all the straight muscles going to the lips and angle of the mouth. That the orbicularis oris is much less affected than these last mentioned, is evident from the perfect closure of the mouth which can be effected. From this fact also, the attempt to whistle, or blow, sometimes directed for the purpose of showing the paralysis, rather diminishes than increases the facial distortion.

The muscles supplied by the portio dura, however, are not the only ones in the face which give evidence of paralysis. The masticatory muscles, though they take no part in producing the distortion of the features, do not altogether escape. If the patient is told to close the jaw firmly, the masseter and temporal of the sound side may be felt to come first into action, and to contract the more powerfully; sometimes those of the affected side only act after two or three attempts.

In the tongue, as in the face, there is evident, but incomplete paralysis, the only manifestation of it being deviation when it is protruded, usually towards the paralysed side.

The abdominal muscles may be made to show a certain degree of paralysis much in the same way as the masticatory muscles. In respiration they act on the two sides with perfect equality, these movements being automatic; but in other actions it may be seen that the muscles of the affected side are weakened. Thus, though an hemiplegic patient is able to raise himself from the recumbent to the sitting posture with little or no help from his sound arm, by means of the recti abdominales, and the hand placed upon the abdomen feels the muscles of both sides contracting powerfully, still as in the case of the masseters, those of the affected side are somewhat later than the others, and do not act with the same energy.

The limbs are the only parts in which motion is altogether lost. In a severe case, I have found not only every muscle of the arm paralysed, but the scapula perfectly motionless. The pectorals, the latissimus dorsi, and trapezius, the latter, in movements of the head also, were flaccid, and apparently the more deeply seated

muscles, the serratus, rhomboidei and levator, were equally paralysed. In the leg, the loss of motor power is rarely so complete as in the arm.

These are the muscles paralysed. It is, however, even more necessary to specify the muscles which escape paralysis, since it is this exemption and not the fact of paralysis which requires explanation. The muscles incompletely paralysed also, will again have to be alluded to, the partial exemption having to be accounted for as well as the complete escape.

The muscles, then, which may give no indication whatever of paralysis are those of the eye, neck, back, and chest. The movements of the two eyes are as perfect as ever; there is no paralysis, therefore, of the third, fourth, or sixth nerves of the affected side. As to the neck, it is sometimes stated that the sterno-mastoid is partially paralysed, but I have never observed this, and in cases where the use of the arm and leg has been entirely lost, I have found the rotatory and the backward and forward movements of the head to be executed as well as ever. Inclination of the head towards one or other shoulder does not seem always as easy as usual, but it cannot be said that any muscles of the neck give appreciable indications of paralysis. No difference again can be detected in the movements of the two sides of the chest, or so far as I have been able to make out in the back. There are other sets of muscles which, without showing any obvious paralysis may be made to furnish evidence of impairment of independent volitional action. These are the levator and orbicularis of the eyelid, the masticatory, and abdominal muscles, as already described. Others, again, are manifestly paralysed, but not completely, as the facial and lingual muscles.

In all these instances, it is the persistence of purely volitional motor power which is spoken of, and not automatic action of any kind. The reflex respiratory movements of the chest and abdomen of course go on, but there remains also the power of taking a deep inspiration, or making a forcible expiration at will, which is not reflex but voluntary. Again, there is the act of rising into the sitting posture executed by the abdominal muscles. So also in the case of the eyelids, in addition to the automatic winking which is not arrested as it is in paralysis of the portio dura, there is the voluntary closure of the lids, more or less firmly. The movements of the eyes have been spoken of as "sensori-motor," but it is evident that they are only so in the same sense as all motion is

influenced by a guiding sensation, and are as strictly voluntary as any movements in the body.

If then, the corpus striatum is to be regarded as the centre of all volitional motor impulses, these exemptions, partial and complete alike, require explanation. So far as I know, this has only been attempted in the case of the facial and thoracico-abdominal muscles, and the explanation has usually turned on the confusion of automatic with voluntary movements.

With respect to the thoracico-abdominal muscles, the explanation usually given is somewhat as follows: "That their habitual and constant action being in the reflex respiratory movements, they are to some extent withdrawn from the influence of the will, and are consequently not affected when voluntary motor power is lost." This which has a very plausible sound will be seen on examination to be absurd. It is in effect, equivalent to saying, that because these muscles are comparatively seldom called into action by the will, it is reasonable to expect that they will still be reached by volitional impulses when other muscles more constantly acted upon by the will are completely cut off from its influence. The persistence of the reflex respiratory movements is easily understood—the mechanism on which they depend is not damaged, but this does not explain the voluntary action still found possible in the muscles of the affected side.

Van der Kolk employs a similar process of reasoning in attempting to explain the exemption of these muscles, by reference to the relation of the lateral columns of the cord with the nucleus of the vagus. These columns have been shown by the experiments of Schiff, to serve for the motions of the trunk, and therefore for the respiratory movements. Van der Kolk finds that their fibres terminate for the most part in the nucleus of the vagus, this connection being part of the respiratory apparatus. He concludes, further, that in consequence of this relation, the function of the lateral columns does not depend directly on the will, though to a certain extent influenced by it, but that they are brought into action specially by a stimulus from the vagus. That is, because these columns form part of an automatic apparatus of which the nucleus of the vagus is the centre, when they are called into action by a totally distinct power, volitional, this also has its seat in this nucleus. His own researches have shown this idea to be untenable. Fibres are found to pass upwards from the vagus, through which the will is supposed to influence the respiratory

movements, and *a fortiori*, these, or an independent set of fibres, must be required for such actions as sitting up. When these fibres are cut across, as they must be in hemiplegia, if they are connected with the corpus striatum, voluntary control over the trunk muscles ought to be lost, whether they pass directly into the lateral column or influence it indirectly through the nucleus of the vagus. The persistence of volitional motor power in the thoracico-abdominal muscles in hemiplegia, therefore, is not accounted for by the relation between the lateral columns of the cord, and the nuclei of the pneumograstrics.

The most recent attempt to account for the partial character of the facial paralysis in hemiplegia, is by Dr. Saunders, in a paper in the 'Lancet' for 1865, vol. ii. p. 478.

After showing that it is the seventh nerve which is paralysed, and not the fifth, as was stated by Dr. Todd, he points out that the facial muscles have three distinct modes of action, as respiratory muscles, reflex; as muscles of expression, emotional; and as voluntary muscles, strictly speaking. He supposes that for each of these different kinds of action, the trunk of the portio dura contains a distinct set of fibres connected at its origin with different excitor centres, volitional, emotional, and reflex respectively, and that destruction of the volitional centre, or of the fibres leading to it, may leave untouched the emotional and reflex centres and communications, permitting the muscles to be called into action through these. Even, if this hypothesis be accepted, it affords no explanation. According to it, purely volitional power should be completely lost, but this is not the case as has been pointed out. A considerable degree of it remains, even in muscles supplied by the portio dura, and, as has before been said, persistence of automatic action does not explain the possession of voluntary control.

In order to be more explicit, and render the insufficiency of this explanation more clear, the orbicularis oculi may be taken as an illustration. The habitual winking movements of the eyelids are automatic—reflex, as they would be termed by some, or sensori-motor, according to others. But we have also the power of keeping the eyes shut at will for any length of time, and of closing them with varying degrees of force, these being distinct exercises of voluntary power. Applying Dr. Saunders's explanation, some of the nerve-fibres supplying this muscle will be connected centrally with the nucleus of the fifth nerve for the

automatic action; others pass to the corpus striatum, and convey the volitional influence. These latter being cut across on one side in hemiplegia, the winking should go on as usual, but the power of forcibly closing the eye of the affected side should be lost. This is not the case, a certain degree of weakness may be apparent, but both eyelids can still be closed at will, and held down with considerable force.

Dr. Hughlings Jackson also, as I gather from a note to the article before referred to, supposes the portio dura to break up within the medulla, and to proceed to different parts of the nervous centres, not, however, precisely on the same grounds as Dr. Saunders, but on account of the wide distribution and varied functions of the nerve. If this were so, it would still fail to account for the persistence of voluntary motion in any of the muscles supplied by it, when the centre of volitional action was destroyed.

But it is an ascertained fact, that the facial nerve does not split up in the way here supposed, and the varied actions, automatic, emotional, and volitional, can be explained without any such hypothesis. The nerve passes entire to its nucleus, and it is by the communications of this nucleus with the different excitor centres, that the various kinds of movement are brought about, with the nucleus of the vagus for respiratory movements, with the fifth for sensori-motor, and with the corpus striatum for emotional and volitional actions. The same fibres in the nerve-trunk convey the impulse from the nucleus to the muscles, from whatever centre the impulse may originally have been derived.

Dr. Jackson has again pointed out the interesting fact, that the muscles of the sense-apparatus escape as well as the special senses themselves, but they are not the only ones exempt, and it is not pretended that any satisfactory explanation is thus obtained.

We come back then to this point, that if the corpus striatum is to be considered the organ of volitional action, an explanation is still required of the incomplete paralysis of the opposite side of the body, neck, and face, when this body is the seat of disease.

The key to this, I believe, is to be found in a comparison of the muscles paralysed with those exempt from paralysis, as to their habitual action. A striking difference is at once noted. Thus the arms (in which the paralysis is complete), are entirely independent in their movements, the one of the other, are altogether dissociated in their action, and habitually engaged in totally

different motions. The muscles of the trunk, on the other hand (which escape paralysis), act in pairs, are almost always bilaterally combined in their action, and the two sides engaged in similar and associated movements. We move one arm, or one leg, while the other is quiet, or executing a totally different action. We find it impossible to expand one side of the chest without the other, or to move one eye without the other, and extremely difficult to throw into action the muscles of one side of the abdomen without the other, impossible, indeed, to do this forcibly.

The parts paralysed then, are such as have the power of acting independently of the corresponding part of the opposite side. The muscles which escape, are those which act only bilaterally, or in concert with the corresponding muscles of the opposite side.

But when muscles habitually act together, and rarely or never independently of each other, the nuclei of their nerves are usually connected by commissures.

The hypothesis suggested by these considerations is, *That where the muscles of the corresponding parts on opposite sides of the body constantly act in concert, and act independently, either not at all, or with difficulty, the nerve-nuclei of these muscles are so connected by commissural fibres as to be* pro tanto *a single nucleus. This combined nucleus will have a set of fibres from each corpus straitum, and will usually be called into action by both, but it will be capable of being excited by either singly, more or less completely according as the commissural connection between the two halves is more or less perfect.*

The existence of this transverse commissural communication between corresponding nuclei is not hypothetical, the fibres have been observed and described, and the association effected by them is considered necessary to harmonious bilateral action, but so far as I know the use here attributed to them, that is of conveying to one an impulse received by the other, has not been suggested.

According to this hypothesis then, if the centre of volitional action of one side is destroyed, or one channel of motor power is cut across, the other will transmit an impulse to the common centre, and this will be communicated to the nerves of the two sides, equally, if the fusion of the two nuclei is complete, and there will be no paralysis,—more or less imperfectly to the nerve of the affected side, if the transverse communication between it and its fellow is not so perfect, in which case there will be a corresponding degree of paralysis.

This will be better understood when illustrated by examples. The nuclei of the two third nerves, for instance, are situated close to the median line, high up in the floor of the fourth ventricle, and are so intimately connected together that they may be considered as one single centre, each half of which receives fibres from the corpus striatum of the opposite side. Supposing now the right corpus striatum be injured, voluntary impulses from the left will pass to the right nucleus only, but the two nuclei being fused into a single centre, this is called into action equally throughout, and the muscles of the left eye act as perfectly as those of the right. In the case of the portio dura on the other hand, the communication between the nuclei is imperfect. Here, then, the same injury having occurred, the left nucleus receiving no impulse from its own motor ganglion, receives only an imperfect impulse through the partial communication between it and its fellow supplied by the uninjured corpus striatum, and the muscles supplied by it are partially paralysed.

Applying now the hypothesis generally, it ought to be found, first, that the paralysis in any given set of muscles is exactly proportionate to the individuality of their action, and their independence of muscles of the other half of the body.

And secondly, when any set of muscles having a certain degree of independent action partially escapes paralysis through association with muscles of the opposite side, that associated movements only are possible on the affected side, and not independent unilateral action of these muscles.

I think it may fairly be said, conversely, that if these tests are complied with, they furnish strong evidence of the truth of the hypothesis. Taking then the different parts of the body in succession, and employing these tests, we find, as I have before stated, that the limbs which alone have perfect unilateral independence of action, are alone liable to complete paralysis in the common form of hemiplegia.

On the other hand, the ocular muscles are never paralysed, and these have no unilateral independence. The two eyes always move together. It is impossible to move one and keep the other fixed, or to turn one up and the other down. Individuals are occasionally met with who can at will exhibit a convergent squint, but this apparent exception to the rule is really only an exaggeration of an associated movement. The centres from which the motor nerves of the ocular muscles of the two sides proceed are inseparably

joined, and if they act at all must act together. We thus also see why strabismus in cerebral affections implies something more than disease of the central ganglia.

In the case of the thoracic muscles, again, we have the same point illustrated; no unilateral independence of action; no unilateral paralysis. Between these extreme cases of complete paralysis and perfect exemption, we have the instances of partial paralysis already enumerated, which afford opportunities for the application of both tests.

The eyelids habitually act together both in the habitual automatic winking, and in the strictly voluntary movements already mentioned, but independent action of one without the other is not impossible. The power of winking one eye is however an educational acquirement, some learn it easily, others with difficulty, others again never master it, and it is not uncommon to meet with persons who can wink one eye alone, but not the other. In hemiplegia accordingly, paralysis is not very apparent in the eyelid. For a time after the attack it is weakened on the affected side, but to render this evident it is often necessary to tell the patient to close the eyes firmly. In accordance therefore with the first test, we have, with little unilateral independence, slight paralysis.

The second test is applied by bidding the patient close each eye alternately. He will be unable to do this on the paralysed side, and in making the attempt it will usually be seen that the orbicularis of the sound side contracts, against the wish of the patient, while that of the affected side remains comparatively passive.

A comparison between the orbicularis oris and the straight muscles, levator, zygomatic, buccinator, etc., again is an illustration of the fact, that the paralysis is proportionate to the independence. It is very easy to draw one angle of the mouth in any direction, the other remaining in position—difficult to compress the lips firmly on one side only. Accordingly, as has been stated, the orbicularis is paralysed to a less degree than the straight muscles.

As to the remaining muscles supplied by the portio dura, in those of the forehead and brow, and of the ala nasi, there is little independence of action and little paralysis. In those of the cheek and lips we have increased independence and marked paralysis.

The movements of these parts are usually symmetrical, and a certain degree of association of the nuclei is presumed to exist, the paralysis consequently is not absolute; but the two sides move

independently of each other with perfect ease from the earliest period of life, this association of the nuclei therefore is only partial, and not sufficient to prevent distortion of the features.

The second test does not give such decided results as in the case of the eyelids. While the paralysis is such as to give rise to marked facial distortion there is no power of independent motion in the affected side; but this soon returns, and may be observed when the eye of that side cannot be closed alone. This may be to some extent due to the power of fixing the muscles on the healthy side.

I have already described the very slight indications of paralysis which may be obtained from the masticatory muscles. This is in exact proportion to the small degree of independent action they possess. The muscles of the two sides always act in concert, and any one making the experiment will find it impossible to exercise any considerable force by the masseter of one side without bringing into action that of the other, even if a hard body be placed between the teeth on the side attempting to act alone.

Again, in the abdominal muscles, the degree of paralysis and the power of unilateral action correspond very nearly with what has been stated of the muscles of mastication. It will be found almost impossible to throw the muscles generally of one side into powerful action without those of the other side. In inclining the body to one side or the other, the rectus abdominis will act without its fellow, and it is in similar movements that impaired power may be shown in hemiplegia.

The tongue furnishes a very interesting illustration of paralysis of unilateral action and exemption of bilaterally combined movements. This organ is usually perfectly symmetrical as to its lateral halves. They are elongated, shortened, flattened, or thickened together; the only unilateral movements are those in which the tongue is carried bodily from side to side and the tip pointed right or left, or in which one margin is depressed and the other raised. The apparent exception to this rule, when one edge of the tongue is rolled up, is produced by pressure of that side against the teeth, and is a result of the lateral motion mentioned. Accordingly, in hemiplegia, there is no loss of symmetry in the tongue; it is still flattened and elongated as a whole; there is no impairment of motility in one half, but there is deviation of the tip when it is protruded.

The complicated arrangement of the muscles of the back makes it difficult to apply the tests to them. It is however certain, that

they give little evidence of paralysis. Many of their actions are automatic, balancing movements, and the two sides almost always act in concert. Even when the body is inclined to one side, the muscles of one side are contracting, to regulate the movement and prevent falling over, while those of the other are employed in curving the spine. In putting a hemiplegic patient through these movements, he readily loses his balance, and it is difficult to make out any difference between the two sides. In attempting to raise the hip he leans over to the opposite side.

The only real difficulty is met with in the neck. As has been already stated, the head is rotated from side to side, or inclined forwards or backwards as readily in a patient with hemiplegia as in a sound man. The inclination towards one or other shoulder does not seem quite so easy or so perfect. The forward and backward movements would be accounted for by the bilateral action of the muscles engaged, the recti antici, and the muscles of the back of the neck. The rotatory movements do not admit of so easy an explanation.

But it is to be noted, that although in rotation no two corresponding muscles are engaged, yet there are associated in it muscles belonging to opposite sides of the body. Thus, in turning the head towards the right shoulder, the left sterno-mastoid anteriorly, and the right inferior oblique atlo-axoid posteriorly, are brought into action, and *vice versâ*. Looking now at the nervous supply of these muscles, it will be seen that it is quite possible for their nuclei to be associated, and indeed very probable that they are, the sterno-mastoid receiving a branch from the spinal accessory, some of the twigs of which come off from the cord at the same level as the second cervical, which supplies the inferior oblique. According to this, then, the left sterno-mastoid in hemiplegia of that side will receive an indirect impulse through the nucleus of the second right cervicol, and so escape paralysis. The association of nerves of opposite sides is not without parallel; as, for example, in the instance of the third and sixth; and the supposition of a relation between the nuclei of the second cervical and spinal accessory, would furnish an additional reason for the scattered origin of the latter.

As to the lateral movements of the neck they resemble the corresponding movements in the back, both sides acting, one limiting, the other effecting the motion.

I think I may say, that the facts here given furnish a con-

siderable balance of evidence in favour of the hypothesis I have advanced. Its simplicity and its general applicability are of themselves recommendations, and I venture to hope that further observation will clear away the few difficulties which remain, and place it, and with it Dr. Carpenter's theory of the function of the corpus striatum, on a firm basis.

Some interesting corollaries might be pointed out, and the association of the nerve-nuclei will be found to bear on other cases than those of hemiplegia, but any discussion of these would be premature.