Associated movements in hemiplegia: their origin and physiological significance

H. Campbell Thomson

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Assistant Physician to the Middlesex Hospital. London

An involuntary association between the movements of paralysed limbs and other parts of the body is a well known thing in cases of hemiplegia. When, for instance, the leg on the unaffected side is voluntarily moved, it often happens that the paralysed leg moves with it, and when a deep yawn occurs the paralysed arm is frequently drawn across the chest with great force. While the mechanism by which these movements are probably produced has been carefully studied the physiological reasons for their existence do not appear to have received so much attention, and, after briefly referring to their mechanism, I shall endeavour to show that, at any rate in some cases, these movements have a definite history in evolution, and that they were once useful for the ordinary purposes of life.

In the case of a complete hemiplegia due, say, to destruction of the internal capsule, it is instructive first of all to enquire what changes have resulted from the lesion in order to allow the associated movements to take place, or, to put the question in another way, to enquire what influences are present in health to prevent them taking place.

The answer to this question is to be found by a consideration of the functions of the pyramidal tracts which are destroyed in such a lesion as that suggested above.

These functions are in the main twofold; the fibres conduct (1) impulses which give rise to voluntary movements, and (2) impulses which exercise a constant inhibitory effect on the lower centres. When these fibres are destroyed there is loss of voluntary power as seen by the paralytic symptoms, and loss of inhibition as seen by the rigidity and increased reflex irritability. It is doubtless this loss of inhibition which allows associated movements, for otherwise there seems no reason why those which occur in hemiplegia should not also occur in health.

With regard to inhibition in the case of the respiratory centre, and the results of cutting it off in hemiplegia, Dr. Hughlings Jackson's observations may be referred to here(Lancet, February 23, 1895).

In hemiplegia, Dr. Jackson found that during ordinary or automatic respiration the amplitude of the superior intercostal movements was greater on the paralysed than on the sound side, while in voluntary respiratory movements the movements were greater on the sound side. Pierce Clark (Am. Jour. Med. Science, December, 19O3.; Sec also some remarks by Dr. Tudson S. Bury, Lancet, December 19, 1903) has recently confirmed this observation and gives the following explanation. "In destructive lesions of the internal capsule causing paralysis, hemiplegic in character, the cortical inhibitory control over the medullary respiratory centre of the paralysed side is destroyed in greater part, at least much more so on the hemiplegic side than to that centre presiding over the sound side; in consequence of this withdrawal the uninhibited medullary centre overacts in automatic. or ordinary respiration, hence excess movements on the paralysed side. But in forced conscious or volitional (cerebral) respiration the movements of the thorax on the opposite sound (or nearly so) side are greater."

It may then I think be safely inferred that the first step in the generation of patho1ogial associated movements is the loss of inhibitory impulses.

Normal inhibition being removed, the second step consists in the simultaneous action of the cells on the paralysed side with those with which the movement is to be associated, thus the cells will act with their fellows of the opposite side in the associated movements of the two legs, or with the cells connected with the respiration in the case of the movement of the arm during yawning. On this part of the subject Sir William Broadbent's classical observations have thrown some considerable light (The British and Foreign Medico-Chirurgical Review, 1886) These observations were made with a view to explain the escape of certain movements. in hemiplegia, and Sir William Broadbent found that the key of the solution lay in the fact that the movements which escaped were those which habitually acted with their fellows of the opposite side, and he attributed this immunity to the existence of free commissural paths between their nuclei, so that impulses could pass from the nucleus on the sound side to the nucleus on the paralysed side. In other words, an impulse from either side of the brain would, through the commissure, reach both nuclei and so cause the bilateral movements to be saved, when the unilateral movements, which have no such convenient commissures to help them, have perished. This hypothesis, which has proved of such importance in the study of neurology, will practically explain the actual mechanism of the posthemiplegic movements. The two stages in the development of these movements would clearly be (1) the removal of inhibitory influences on one side by destruction of the pyramidal fibres; and (2) action in conjunction with adjacent nuclei, brought about by impulses passing along commissural fibres. I would again lay stress on the fact that the first step must be the removal of inhibition, which has gradually become developed as the education of the limbs for isolated and special movements has proceeded, for had this inhibition not been developed both legs would probably move simultaneously like the movements for closing the eyes. Another point to be observed is that the constant presence of inhibitory influences leads to gradual disuse of the commissural fibres until finally it becomes difficult, or even impossible, for impulses to pass along them at all. This effect is well seen if we again for a moment compare the effects of a hemiplegia on movements for closing the eyes with movements for the legs. Those for closing the eyes are scarcely, materially altered, for the two sides have not yet become educated to act independently of one another; the commissural path betwen their nuclei is easily traversed, and the nuclei are in a condition to receive and to act from the impulses that come along it. On the other hand, the legs are so much in the habit of being moved separately that their commissural fibres have become disused, and when the inhibition is taken off, as it is in hemiplegia, the disused paths are of but little use and the movements of the limb suffer in proportion.

But while Sir William Broadbent's theory accounts for the mechanism of the movements after inhibition has been removed, it will be noticed that so far from all these movements being beneficial like those of closing the eyes, they are often useless and even actually detrimental. Only to be able to move the two legs together, though possibly little better than not being able to move them at all, can be of very slight use, and it is certainly both useless and unpleasant to have the arm drawn across the chest during the act of yawning.

The commissural fibres which allow these movements to take place must once have had their uses or they would not have been developed, and therefore it is reasonable to suppose that impulses which were of some importance once flowed along them, and that as these impulses ceased the paths gradually became disused. When, however, the influences that keep the impulses from flowing along them are removed, the old disused routes are again traversed although the results may no longer be advantageous to the individual. These associated movements of hemiplegia may then be looked upon as a faint reflection of movements which have gradually become obliterated in the process of evolution, and I shall now endeavour to trace out how these movements originated and what purposes they previously served. In the first place evidence seems to show that all movements were originally bilateral. The passage of bilateral movements into unilateral ones can be easily traced in man, and in every one, many movements which were primarily associated tend to become dissociated, and the dissociated ones then become still further specialised for particular purposes.

We have only to compare the arms and hands of man with the forelegs and feet of animals to realise this.

Thus the question of loss of power in hemiplegia may be approached from another standpoint, and we may ask, not why some movements escape in a unilateral lesion, but why some are lost, for working upwards from the time when all movements were bilateral it will be seen that the escape of movements in a one-sided lesion would be the natural thing to happen, and that their loss is the result of a gradual dissociation and specialisation. The involuntary associated movements of the two legs in hemiplegia are, according to this supposition, the representation of the bilateral movements of the legs which at one time served as the chief means of progression.

When bilateral symmetry was first attained (which it was at apparently a very early period of animal evolution), all movements including those of the limbs were doubtless bilateral, and this mode of progression still remains in various animals, as in the leaping of frogs and the hopping of many birds. Progression by alternate movements of the legs is a later attainment, and the tendency to revert to the more primitive method may often be seen in animals when they are under the influence of excitement. The horse and the bull, for example, usually walk or trot, but when angry or frightened they tend to gallop. As the art of walking by separate movements of the legs is acquired, the movenents of the two forelegs become associated with those of the two hind legs, but in such a manner that the left fore-limb moves in conjunction with the right hind limb and the right fore limb with the left hind limb. This diagonal association of the limbs is still seen in man at the present day by his tendency to swing the arms alternately with the legs in walking. To abstain from swinging the arms in this way is an effort and can only be accomplished with some trouble (Sir William Broadbent alludes to this point in his recent "Hughlings Jackson" Lecture (BRAIN, Pt. ciii.). He says: "I think a further exemplification of the principle (i.e., the bilateral association of nerve centres) 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 versâ, 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.")

Man has entirely lost the more primitive mode of progression by the simultaneous movements of both legs, and he never apparently finds any reason to resort to it unless it be when he jumps, and even here in most cases one leg tends to hang behind the other. Such a mode of progression would be of no advantage to him after he assumed the upright position. But although obsolete in health the old association shows itself again when the inhibitory influences which check it are removed by disease.

When the inhibitory impulses cease to exist the memories of the old bilateral movements assert themselves, but the paths have become difficult to traverse and only a feeble impulse can get through to produce a correspondingly feeble movement (It seems probable that the comparative escape of the leg in hemiplegia is due to the existence of these commissural fibres rather than to those connecting the arm and leg as suggested by Sir William Broadbent).

The circumstances which give rise to involuntary movements of the arm during yawning are not quite so obvious, for it is not apparent at first sight why the two movements should have ever been associated.

That the occurrence of these movements is dependent upon the removal of inhibitory influences is clear from what has already been said, and it is interesting to note that the dissociation has not yet become quite complete even in health, for the involuntary stretching of the limbs during a yawn is familiar to every one.

In one instance I have observed that deep yawning is occasionally accompanied by some involuntary jerky movements of flexion of the left arm, quite different to the ordinary stretching of the limb and much more nearly approaching the movements one sees in hemiplegia. It is also interesting to note that in this case it was the left arm which moved, for in a right-handed man one would expect the left arm to be less specialised and therefore less strongly inhibited than the right.

In hemiplegia the paralysed arm is often drawn across the chest with very great force and at the same time the leg may be drawn up. In order to arrive at some conclusion with regard to the meaning of this association it is necessary to consider some aspects regarding the development of the function of respiration.

If we go back to the fish we find the lungs represented by a swim-bladder, the chief use of which is to allow the fish to vary the depth of its position in the water. Compression of this bladder appears to be accomplished usually by the lateral muscles of the body, though in some cases there is a distinct muscular coat developed in the bladder wall. The two pectoral and the two ventral fins are the homologues of the future limbs, and it is interesting to note that the chief function of these is not yet one of progression, but rather of balancing the body of the fish, and in performing this duty thes fins appear to act to a considerable degree in connection with the condition of the air bladder. Cuvier says: "The pectoral and ventral fins do not appear of much use in the progress of fishes, but they employ, them to preserve themselves in a state of equilibrium or a state of rest, and they extend them whenever they find it necessary to correct the vacillations of the body."

The nerve supply of the air bladder in fishes is the vague, as it is that of the lungs in later development, and in some species this nerve sends fibres to the pectoral and ventral fins from its lateral branches. There are then even in fishes, before any lung respiration is developed, some signs of association between the representatives of the future limbs and the future lungs.

Lung breathing appears at first to be developed as a supplementary aid to branchial respiration, and the fish or amphibian that cannot obtain sufficient air from his watery surroundings seeks more by coming to the surface of the water and swallowing it ("Principles of Biology," by Herbert Spencer, vol. ii., p. 835).

Repeated deglutition of air bubbles finally results in the differentiation of the lungs from the swim-bladder, but it seems obvious that as soon as the animal begins to feel the benefit of exchanging its air in this way, and habitually practises this method of obtaining it, the getting rid of the air must be quite as much a voluntary effort as taking it in. It is only later that the respiratory acts will become controlled by automatic centres. Respiration, more especially expiration, will no doubt at first be effected by the trunk muscles, and the nervous mechanism employed will not at that time be specially differentiated, and it is probably these early centres further developed which survive to the present day as -subsidiary respiratory centres in the cord, of which more will be said later.

In making these early expiratory efforts the animal would find it necessary to have some fixed point for the muscles to act from and this would naturally be obtained by fixing the limbs, a piece of knowledge which is inherited by man and put to practical use when he voluntarily brings his extra respiratory muscles into play, as in asthma.

Another interesting piece of evidence concerning the association between movements of the limbs and respiration is furnished by the Chelonia, to which class belong the turtles and tortoises. In Owen's work on comparative anatomy it is stated that the lungs of these animals are lodged in a cavity the capacity of which is only affected by the retraction and protrusion of the limbs and tail, and that if a turtle is thrown upon its bak, and makes an inspiration, its four feet are erected, the breast bone is pushed forward, and the cavity swells out wherever the parts are soft, and it is suggested that all this is done by the muscles of the extremities moving their respective bones in an inverted order; that is, the extremity becomes the fixed point from which the other bonds move (Respiration can also be carried on when the limbs are motionless, apparently by acts of deglutition. y. Owen's "Comp. Anat”).

Next, it will be well to consider the subsidiary respiratory centres that still exist in the cords of mammals, and which, no doubt, represent centres that at one time took a very important, if not the chief, part in the functions of respiration. Sir Michael Foster, in his text-book of physiology, states that in young animals, under certain conditions, respiratory movements may be carried out with entire absence of the spinal bulb, and that these rhythmical respiratory movements are sometimes accompanied by rhythmic movements of the fore and hind limbs.

It should, however, be stated that Sir Michael Foster for some reason does not consider that these movements of the limbs are respiratory in action, and owing to their presence he doubts whether the experiments really prove the existence of distinct respiratory centres in the cord, but unless there is any special reason for thinking otherwise it would seem reasonable to believe that the movements in question, represent an association between the movements of the limbs and those of respiration. Moreover, to some authorities these centres have a higher significance, for Sir Michael Foster goes on to say that some consider them to be the chief centres which the bulb merely governs. Anyhow, this probably their position at one time, until they graduallly lost their independence as they came to be more and more under the control of the higher centre.

Because these centres are unable to carry on respiration when the bulb is destroyed it must not be too hastily assumed that they are necessarily so useless when the mechanism is complete, for it may be that under the influence of the bulb they discharge duties which they are unable to do as soon as that influence is removed.

To sum up, then, it would appear that the evidence goes to show that respiratory movements in animals were originally closely associated with movements of the limbs, and it seems likely that it is this association that accounts for the presence of commissural fibres between the nuclei which preside over th two movements. As the respiration became more thoracic in character its association with the legs would become weakened, and then, later on, the movements of the arms would gradually become dissociated as they became educated to perform more special movements, for the inhibition required for these finer movements would effectually prevent any movement taking place with respiration, which, if allowed, would obviously destroy the utility of the arms for other purposes. At the same time the increasing automatic action of the respiratory movements would also tend to make ordinary respiration independent of any support from the limbs except in cases of difficulty, and thus the movements of respiration and of the limbs, at first intimately associated, would gradually drift apart until finally, with the development of inhibition on the one hand, and with the disuse of the commissural paths on the other, the association would practically altogether disappear, but as soon as the inhibitory impulses are taken off the limb again tends to resume its old relations, the unused paths become reopened and the old associations are revived; In health these paths have still, in this instance, been used a little during yawning, so that their obliteration has never been quite complete. Yawning is a peculiar respiratory act in thany ways and is certainly more automatic than ordinary breathing. According to Sir Michael Foster the stimulus in yawning probably acts upon the respiratory centre itself; possibly the centres in the cord also take a share in it, but in any case yawning may be looked upon as a lower type of the respiratory process than ordinary respiration, and therefore the one with which the movement of the arm would be likely to be longest associated.

Darwin's first principle in his work on "The Expression of the Emotions" is "that movements which are serviceable in gratifying some desire, or in relieving some sensation, if often repeated, become so habitual that they are performed, whether or not of any service, whenever the same desire is felt, even in a weak degree". I would then suggest that these post-hemiplegic associated movements are in keeping with this principle inasmuch as they represent movements which were once serviceable, but which have now ceased to be so. These movements, though scarcely discernible in health, have not, however, yet become entirely obliterated, and they are still able to show themselves clearly when the restraining influences that normally check them are removed.