INCO-ORDINATION.

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"THERE is no paralysis, but there is inco-ordination," is a common phrase. What does it mean? It is considered a complete description, and in great measure an adequate explanation of a motor defect, to say that it is "a loss of co-ordination." But what is co-ordination? To say that a patient cannot walk because he has lost the power of co-ordinating the movements of his legs, is like saying that opium causes sleep by means of its soporific virtue. Unless we can attach some meaning to the term inco-ordination much more definite than is ordinarily attached thereto, we are guilty of what Comte called a metaphysical explanation, or what may perhaps be better termed a verbal explanation,—an explanation which solves the unknown in terms of the still more unknown, and so is no explanation at all. Until quite recently, the word inco-ordination has occupied in medical terminology the position formerly occupied for so long by the term "reflex action." It has been applied to the residuum of unexplained things, and has served in lieu of an explanation. Of late, however, it has begun to be hewn into shape, and the true meaning of a very important term is beginning to emerge from the matrix in which it potentially though not actually existed, as a statue exists in a block of marble. It is no longer regarded as an isolated function, like that of coughing or sneezing, resident in, and confined to, a particular region in the cord or cerebellum. It is no longer supposed that, when a centre in the brain has issued the discharge necessary for a certain movement, this current of force has to go through some subordinate centre to be "co-ordinated" before it is passed into the muscles. It is pretty generally understood that as co-ordination exists in every movement, so it forms part of the

function of every motor centre. But still it does not appear to be quite determined what precise element in a movement co-ordination is, or what precise portion it forms of the functions of a nervous centre; and an attempt to determine its nature still more accurately may therefore be of service.

Muscles act, not singly, but in groups. Every movement of a limb, for instance, is brought about by the contraction, not of one muscle but of several, it may be of many; and involves the relaxation, or rather the elongation, of several more. The actual movement of the limb is therefore the resultant of the movements of the muscles concerned. Suppose that the contractions of three muscles pulling in different directions, and each acting with a certain force, produce movement of a limb in a certain direction. If now the action of all the muscles is enfeebled, and all are enfeebled to a proportionate (not an equal) degree, then the resulting movement of the limb will be in precisely the same direction as before, but it will be less forcible. But if one of the muscles is paralysed, the pull in one direction being absent, the movement of the limb resulting from the action of the remaining two will be in a new direction, and will differ in force from the former movement. And if this muscle, instead of being paralysed, is merely weakened, the others remaining as before, the movement of the limb will still be altered in direction, though to a less degree. Or, on the other hand, if one muscle of a set contract too forcibly, the resultant movement of the limb will be in a new direction. So that when a movement is enfeebled, all the muscular contractions that go to make up that movement must be proportionately (not equally) enfeebled; and when a movement takes a wrong direction, it is because the muscular contractions that produce that movement are combined in wrong proportions—are wrongly adjusted—are inco-ordinated. In this case, therefore, an inco-ordinated movement means a movement whose component contractions are combined in wrong proportions.

Let us now take another case of inco-ordination. The movement is in the right direction, and is of appropriate force, but it is carried too far. Such a movement is seen in stringhalt. What is the defect in such a case? By hypothesis the movement is in the right direction, and therefore the several

muscles that produce it must contract in proper proportions,—must be co-ordinated in so far as the force of their contractions is concerned. But they all contract too far, the relations among them remaining undisturbed. Now, other things being equal, the extent of a contraction depends on the time that it continues; and the duration of a contraction remaining constant, its extent depends upon its rapidity. Hence, if a movement is carried too far, it is either too long continued, considering its rapidity, or it is too rapid, considering its duration. In other words, the rapidity and the duration of the movement are out of proportion to one another.

Take another very simple form of inco-ordination,—Tremor. Tremor is normal muscular contraction magnified in Time. We know that if a strand of india-rubber is nicked at intervals with a knife, so long as there is no tension upon it, the cuts are imperceptible; but directly the cord is stretched, the cuts gape; and the longer it is pulled, the wider do the notches become. Much in the same way, the several simple contractions that compose a muscular action are imperceptible so long as they remain in close apposition to one another, but when they occur more slowly—when the time over which they are spread is stretched—then the gap between one contraction and the next becomes apparent. In other words, tremor occurs when the number of simple contractions is too few for the time over which they are spread—when the number in a series is out of proportion to its duration.

The movements in tabes dorsalis are wrong in direction, excessive in extent, and wrongly proportioned in time. In each respect they come under one of the previous headings, and the sum total of the defect may therefore be expressed as a combination in wrong proportions of the forces, times of occurrence or durations of the component muscular contractions. The movements in chorea, widely as they differ from those in tabes, agree in being inco-ordinated movements, agree in being wrong in direction, excessive in extent, and wrongly proportioned in time, and agree therefore in being expressible as combinations of muscular contractions in erroneous proportions. In stammering, some sounds, that is some muscular actions, are too prolonged; others do not come into play soon

enough; and others occur at wrong times; and in each case the defect is that the times of the actions are combined in wrong proportions.

Now take a much more elaborate case of inco-ordination, such a case as ocular vertigo. In this case, owing to the paralysis of an ocular muscle, the position of external objects as ascertained by sight is misinterpreted; the floor, for instance, is seen with a different inclination from that which it actually has. Now the compound motor arrangements which keep the body upright serve to give us in another way a knowledge of the position of external objects, and especially of the inclination of the supporting surface. Normally the impressions from the outer world received by these two routes harmonise with one another, and blend into a single percept, just as the two separate images received by the two eyes blend into a single percept; but when, owing to an erroneous interpretation, the group of impressions arriving by one route contradict the group of impressions arriving simultaneously by another route, there results a state of confusion which we term vertigo. Vertigo, then, results from the combination of a normal arrangement with a defective arrangement, in other words, it is due to the combination of motor arrangements in erroneous proportions.

In short, every motor derangement which is not either a simple defect or a simple excess must be an alteration in the proportion of the constituents of the movement to one another. There is no other alternative. If a movement is simply weakened, then all its components are proportionally diminished. If it is simply excessive, then all its components are proportionally increased. If it is erroneous in any other way whatever, it is a case of inco-ordination, and it results from a change in the proportion of the elements or factors of the movement to one another. Be they factors of space, or time, or force, the alteration must be in the relations among them, since no other alteration is possible.

Inco-ordination, then, is alteration of proportion; but not every alteration of proportion is an inco-ordination. We have seen that every variation in the movement of a part, whether a variation of direction, or extent, or rapidity, or duration, is

due to a variation in the proportions of the elements of the movement. But the variations in the normal movements of a part are literally infinite. The hand, for instance, can be moved to any one of an infinite number of positions within its range. Yet every one of these movements may be normally performed and thoroughly co-ordinated; so that a distinction must be drawn. Although it expresses the truth to say that inco-ordination is an alteration of ratio, it does not express the whole truth. A limitation is required.

When we compare the altered movements of disease as a whole with the movements of health, we find that there is one quality which is never absent in the latter, but which is conspicuously and invariably deficient in the former, and which indicates broadly the division between them. This is the quality of definiteness or exactitude. A normal movement begins at a definite time, traverses a definite path, and ends at a certain place and at a certain time. Abnormal movements have no such precise limitations. The movement of a tremulous hand begins indefinitely, as an exaggeration of the tremor; its path is vague, wandering and exact. It ends by subsiding into simple tremor. In the normal movement of walking, each leg is moved at a definite time, to a definite extent, to a definite spot, on which it is planted with a certain force; but in reeling or staggering it is impossible to know beforehand, with any approximation to exactness, when the next step will begin, what will be its direction, how long it will last, or how forcible it will be; and the total movement compounded of these several movements is similarly indeterminate; the body sways conspicuously from side to side; the course deviates now to the left and now to the right; and the variations of every kind are irregular, ununiform, unpredictable, indeterminate. Similarly with the movements of handicraft. In a normal movement of prehension, the hand is put forth straight to the object, which is then grasped by a direct and well-defined movement. But when a choreic patient attempts to grasp an object, the hand wanders about in a vague and indefinite manner on its way to the object, and when this is reached, the movements of grasping it are numerous, indirect and indefinite. When a healthy person is

told to put his finger on his nose, the finger comes straight down upon a definite spot. But when an ataxic patient attempts the same movement the hand wavers about, and the finger finally comes down, not on this spot or that, but anywhere in the neighbourhood. In normal articulation each word and each syllable has its definite duration; but in stammering there is no exactitude. Long syllables become short, and short ones long, and the lengths of all are uncertain; they become fused together; the outlines are blurred. In still more complex cases of inco-ordination the character of the defect remains the same. Wherein do the purposive movements of a worker differ from the incoherent flounderings of a hysterical girl more conspicuously and more fundamentally than in their superior exactitude? And in what consists the still wider divergence of the shouting and whirlings of acute mania save in their still greater indefiniteness of limitation both in time and space?

Inco-ordination we have previously found to be combination in erroneous proportion. We now see in what the error consists. It is in the substitution of an indefinite for a definite proportion; and the needed limitation is added to our conception of inco-ordination when we define it as *combination in indeterminate ratio;* co-ordination being combination in determinate ratio. Such a definition appears to include everything that co-ordination is, and to exclude everything that it is not. It applies not only to the co-ordination of the elements of movements, to the combination of the spaces, times and forces of the muscular contractions that go to make up a movement; not only to the combinations of movements with one another; but to that combination of impressions with movements which is the highest form of co-ordination, and which constitutes the raw material of Conduct.