VII. "On the Analysis of Voluntary Muscular Movements by certain new Instruments." By WILLIAM R. JACK, M.D., B.Sc. Communicated by Professor J. G. MCKENDRICK, F.R.S. Received January 25, 1895.

(From the Physiological Laboratory of the University of Glasgow.)

(Abstract.)

The object of this investigation was to determine the greatest speed of which the voluntary muscular movements were capable, and how far the speed was influenced by age and education. It was decided to limit the research to a study of the movements of the fingers, as being the easiest parts to examine of the muscular system. The writer has to acknowledge his indebtedness to Professor McKendrick for much valuable assistance and advice.

The first instrument used was one devised by Professor McKendrick, and figured at p. 78 of his 'Life in Motion' (first edition, 1892). It consisted essentially in a tuning fork, carrying a smoked microscopic slide, and set in motion by a bichromate cell. With all its loads, the fork made 117 double vibrations per second, as determined by the chronograph. Lines drawn upon the attached slide perpendicular to the plane of vibration were, therefore, thrown into waves, each of which represented the space passed over in 1″/117. The different movements investigated in this way were the following:—(1.) The greatest velocity attainable by the single contraction of one finger, to which a finely-pointed needle was affixed. (2.) The greatest velocity attainable by the single contraction of the fingers in combined action. For this purpose the needle was fixed in a penholder, and held like a pen, care being taken to see that there was no movement of the wrist, but only of the fingers. (3.) The greatest velocity obtainable in ordinary writing. In this way, therefore, the velocities of a series of movements increasing in complexity could be compared. The velocity of curves and of curvilinear figures was also compared with that of straight lines.

Twenty-three normal and two pathological cases were examined. The normal cases were divided into three classes: those of special manual education (musicians), those of average manual education (the ordinary educated classes), and those of inferior manual education (working men), in whom the hands were accustomed only to coarse movements, and the fingers had no special training. Of the first class there were five examples; of the second and of the third, nine. The ages varied from 18 to 62.

While the tracings were being made the hand rested on a little table at the height of the recording slide. It was found that the

velocity of the more complicated movements could be increased to some extent by practice. Only a few preliminary tracings, to accustom the hand to the instrument, were therefore allowed to each subject, in order that all might be as much as possible on the same footing. Full details of the velocities attained in each case, and figures of the apparatus used, are given in the original essay. In this abstract only a statement of the results attained will be made.

It is not contended that the figures there given represent the absolute velocities of the movements made, for the retarding influence of friction on the slide has to be allowed for, and the increase in the space travelled over through the extension of the needle beyond the end of the fingers. But, as all the subjects were under the same conditions, a comparative estimate of the velocities may be arrived at.

Beginning with the influence of training upon the velocity of the movements, the pen-movement was first studied, and the rate at which a distance of 3 cm. in the middle of the slide was traversed was taken as the standard of comparison. Unfortunately no tracings of this movement were taken from musicians, but, on comparing the average of the tracings derived from those of average and those of inferior manual education, the following conclusions were arrived at.

(1.) That in those of inferior manual education (whose two hands were both untrained) the velocity is equal in both hands (3·4″/117 for the right and 3·5″/117 for the left hand).

(2.) That in those of average manual education the velocity is greater in the right hand, which has been trained (as in writing) than in the left, which has not (2·9″/117 for the right and 3·6″/117 for the left hand), an exception being found in the case of the author, both of whose hands had been pretty equally trained, in which case both had the same velocity (3″/117).

(3.) That the velocity is greater in the right hand of those of average education than in the right hand of those of inferior education.

(4.) That the velocity in the left hand (which has been little trained) of those of average education is practically identical with that in the left hand of those of inferior education.

The velocity of contraction of a single finger was next examined with the following results:—

(1.) That the velocity is equal, or nearly so (2″/117) in the first and second fingers, and is greater than that in the third and fourth, which have also a nearly equal velocity. This may be due to the special arrangement of the tendon of the extensor communis digitorum for the third finger, and for the fourth to the awkward position in which it was placed.

(2.) The velocity of each finger is practically identical for the two hands.

(3.) That the velocity of the finger-movements is not appreciably affected by manual training. The most rapid single contraction of the fingers of a trained pianist is very slightly, or not all, faster than that of a working man.

(4.) The velocity of movements of flexion is on the average slightly greater than that of movements of extension, although in two of the eight cases examined the velocities were identical.

(5.) The velocity of the finger-movements, as a whole, is greater than that of the pen-movements.

In examining the more complicated movements of writing it was found:—

(1.) That the average velocity is practically the same in musicians and in those of average education, their training in this regard being nearly equal.

(2.) That the velocity in the untrained working-classes is much less than in the two former.

(3.) That the velocity in all classes is much less than in the pen-movements.

(4.) That the curved parts of letters and figures are more slowly formed than the rectilinear parts, and that the velocity of a curve varies, roughly speaking, with the radius of curvature.

The difference, then, between education and the want of it is greatest in writing, less in pen-movements, and scarcely noticeable in the simple finger-movement. And the average velocity for all classes is least in writing, much greater in pen-movements, and greatest in finger-movements. The velocity therefore diminishes, and the difference between the various classes increases as the movements become more complex. The more nearly they approach to a simple muscular contraction, the less is the difference noticeable; though it would, doubtless, be found that the musician is able to repeat a series of simple muscular contractions much more rapidly than one with untrained fingers.

The influence of age upon the velocity of the movements was next investigated, and it was found, with regard to writing:—

(1.) That the velocity of the movements of writing becomes slower with advancing age.

(2.) That it is greatest between the ages of 20 and 29, and decreases with every decade thereafter.

(3.) That this decrease is greater in the uneducated than the educated.

With regard to pen-movements it was found:—

(1.) That the decrease in velocity is less marked than in the case of writing.

(2.) That the velocity is greatest between the ages of 20 and 29.

(3.) That the difference in the rate of decrease between the

educated and uneducated classes is not so marked as in the case of writing.

With regard to finger-movements it was found that they retained nearly the same velocity for all classes between the ages of 20 and 50; and that in the one case of a man over that age (a labourer, æt. 62) there was a decided decrease.

In the two pathological cases investigated, one of lateral sclerosis in a man of 41, and one of tremor of the hands, following upon syphilis, in a man of 50, similar results were obtained. For the complex movements of writing were most seriously retarded, the pen-movements less, and the finger-movements least of all.

It appears, then, that as a movement increases in complexity, and involves in its performance the associated action of a greater number of muscles, its velocity diminishes, and the influence of education becomes more distinctly manifest. And as complex movements require a longer education for their rapid performance, so they appear to become sooner defective than the simpler movements. For it is in writing that the retarding effect of age is most apparent, while it is least so in the finger-movement.

In the second part of the investigation it was desired to obtain tracings from a larger series of contractions than could be registered upon a microscopic slide. For this purpose new instruments were required, and owing to the long delay in making these, but few experiments have been recorded. The instrument finally adopted consisted in a long steel bar, held firmly in an iron clip, and carrying in a clamp attached to one end a smoked glass plate 6 inches square. It was set in motion by an electro-magnet through which passed the current from a storage battery, and, as determined by the chronograph, it made fifty-four double vibrations per second. At Professor McKendrick's suggestion it was determined rather to investigate with this instrument the phenomena of fatigue, a purpose for which he thought it very suitable. With this object, Mosso's ergograph was adapted to the instrument, the recording part of which could be pulled on rails slowly away from under the registering lever, which worked up and down with the movement of the weighted finger. Thus a series of contractions and relaxations, divided by the oscillations of the bar into fifty-fourths of a second, was registered on each plate. The plate could be taken out, and a new one substituted, beneath the lever, without stopping the movement of the finger. A key was interposed in the circuit to shut off the current while the plates were being changed.

Four normal and two pathological cases were investigated, series of tracings being taken with a $\frac{1}{2}$ kilo., a 1 kilo., and a 2 kilo. weight. They show in a very striking manner the diminution in height of the contraction, and the coincident diminution in its velocity, due to

fatigue. The measurements which were taken of the rates of velocity at different parts of the tracings afford somewhat varying results, and the number of cases is too few for any definite conclusions to be drawn from them. But it would appear that while the diminution is gradual and uniform in the case of small weights, in that of larger weights it occurs, as a rule, more rapidly, and that the rate of diminution does not remain the same throughout the tracing.

VIII. "Experiments upon the Influence of Sensory Nerves upon Movement and Nutrition of the Limbs. Preliminary Communication." By F. W. MOTT, M.D., F.R.C.P., and C. S. SHERRINGTON, M.D., F.R.S. Received March 7, 1895.

In the 14th of the 'Leçons sur la Physiologie et la Pathologie du Système Nerveux,' Claude Bernard draws attention by experiments on the frog and on puppies to the degree of impairment in movement undergone by a limb that has been rendered insensitive by section of the sensory roots of its spinal nerves.

In a series of experiments carried out during the last eighteen months, we have examined the same thing in the monkey, using chiefly *Macacus rhesus*, and observing the animals for periods up to four months from the time of operation.* We propose to give here a brief account of the results obtained.

Our experiments deal separately with the lower limb and with the upper limb. The phenomena observed in the two limbs do not essentially differ, but are rather more marked and much more accessible to examination in the case of the upper limb.

I. *On Movement.*

(1.) *Effect of Section of the whole Series of Sensory Roots belonging to the Limb.*—By the "whole series" is meant in the brachial region from the 4th cervical to the 4th thoracic inclusive; in the lumbar from the 2nd to the 10th post-thoracic inclusive.

From the time of performance of the section onwards, as long as the animal may be kept, the movements of the hand and foot are practically abolished; the movement of grasping, which is so frequent and useful to the monkey, both with the hand and foot, never occurs at all in our experience. On the other hand, the movements at the elbow and knee, and especially the movements at the shoulder and hip, are much less impaired. The fore limb hangs from the shoulder partially flexed at the elbow; the hind limb is flexed at hip

* In all our operations the animals have been deeply anæsthetised with chloroform and ether.