Observations on the Analysis of voluntary muscular Movements by certain new Instruments,

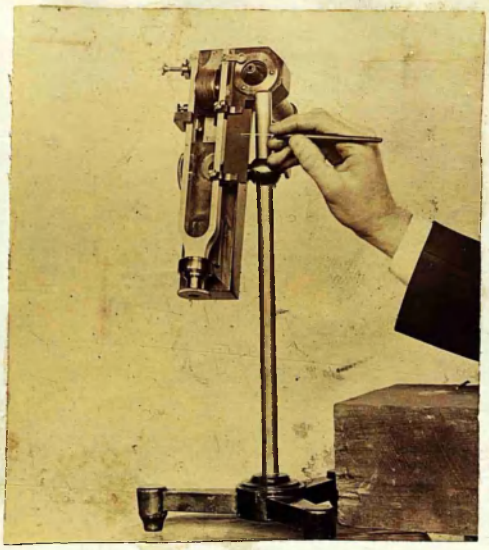
by

William R. Jack, M.B., C.M., B.Sc.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

In the winter of 1892 I was asked by Professor Mackendrick to undertake an investigation into the rapidity of the voluntary muscular movements, of which the present essay is an account. The work has been subject to considerable interruption. In the summers of 1893 and 1894 my time was fully occupied in teaching, and in the winter of 1893-94 a period of several months was occupied in devising new instruments. Several forms of these were tried, and altered in one or other detail to suit the special purpose. During this time it was impossible to carry on the experiments. Consequently they are somewhat limited in number, and the results derived from the later instruments are so few as merely to indicate what they may be expected to perform.

The object of the investigation was to determine the greatest speed of which the voluntary muscular movements were capable, and it was decided to limit it to a study of the movements of the fingers. I have at the outset to acknowledge my indebtedness to the kindness of Professor Mackendrick for much valuable assistance and advice. The first instrument used in the experiments was one devised by him some time previously, and figured at p. 78 of his book "Life in Motion" (1st edition, 1892). It consisted essentially in a tuning-fork carrying a smoked plate. The unloaded fork gave 128 double vibrations per second. One limb carried a microscopic slide, attached to it by two brass clamps bearing steel spring clips, between which the slide was placed. A counterpoise was attached to the other limb. The apparatus was fixed to a wooden block, which could be slid up or down the upright of a heavy iron stand by means of



The instrument is figured in a vertical position, to show its various parts. In use, it was placed horizontally, and the arm rested on a table or stool, as stated in the text.

a screw. To support the arm of the person experimented upon, a light wooden stool was made, with one side of the top cut out so as to fit closely round the smoked slide. The subjoined figure illustrates the apparatus.

The loaded fork was found, by means of chronographic tracings, to give 117 double vibrations per second. A contact-breaker of platinum wire was attached to the apparatus, and the whole was set in motion by a bichromate cell, the wires from which were attached to binding-screws in connection with the instrument. When the apparatus was in motion, lines drawn upon the smoked slide, perpendicular to the plane of vibration, were thrown into waves, each of which, in the absence of retarding friction on the slide, represented $\frac{1}{117}$". In order as far as possible to avoid friction, those who made the tracings were instructed to press as lightly as possible, but some allowance must be made for even the slightest pressure in retarding the motion of the fork. The note (B♭ on the bass clef, approximately) emitted by it, however, did not perceptibly vary during any of the tracings. They were taken at first with a finely-pointed needle fitted into a penholder, and held like a pen, the subjects being carefully watched to see that only the fingers moved, and not the wrist. When it was found desirable to study the action of separate fingers, a short piece of wood was taken and hollowed out so that the finger might lie in it. A needle was inserted at one end, and it was then firmly fastened to the finger. By this means tracings of a single contraction of one finger could be obtained. These tracings cannot be

taken as absolute time records of the muscular rapidity, for two reasons:- (1) the friction on the slide must be allowed for; (2) the projection of the needle-point beyond the finger increased the size of the arc through which motion took place. But these factors apply equally to all the cases, so that an accurate comparison of the rapidity in different individuals can be made.

I began my experiments by taking a series of tracings from my own fingers. In some of these the penstroke was used, and in others the needle was attached to one finger only, with which a single twitch was given. At first I measured off a space of 3 cm. in the middle of the slide, and counted the number of waves required to traverse this space, where the finger was moving most quickly. This of course gave the time in $\frac{1}{117}$ ths of a second. With regard to the pen movement, I found that the velocity, at first comparatively slow, increased considerably with practice, so that it became necessary, in order that the tracings from all subjects might have an equal value, to allow only a few preliminary trials for the purpose of accustoming the hand to the movement. Thus in six slides (Series A), taken on two consecutive days, the velocities were

7	$6\frac{1}{2}$	$5\frac{1}{2}$	8	7	8
6	$8\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	6
9	9	$7\frac{1}{2}$	$8\frac{1}{2}$	9	5
5	8	8		8	7
4		8			

giving an average velocity of $\frac{7{\cdot}08}{117}$". In five slides, (Series B) taken five days afterwards, the velocities were

7	6	5	5	7
6	4	4	5	$4\frac{1}{2}$
4	4	4	$4\frac{1}{2}$	5
5	5	3	$4\frac{1}{2}$	5
	3	3		5
				3

giving an average velocity of $\frac{4{\cdot}6}{117}$". The maximum velocity was

$\frac{3}{117}$". I then proceeded to take tracings of the same movement from the left hand. These were done the day after series B. In four slides (Series C), the velocities were

$6\frac{1}{2}$	4	6	4
$4\frac{1}{2}$	4	5	5
5	3	4	$4\frac{1}{2}$
5	5	8	4
5			

giving an average of $\frac{4 \cdot 9}{117}$", very slightly less than the velocity of the right hand, while the maximum velocity, $\frac{3}{117}$", was the same for both hands. I am, however, in the habit of using my left hand more than usual, and am practically ambidextrous.

The figures hitherto given are from rough measurements made at the time. They will be more accurately stated in the sequel.

I now passed to the examination of curved lines and figures, drawn as quickly as possible upon the moving plate, the needle being held like a pen. In a large series of these plates, a few of which have been preserved as examples, I found that the velocity was very notably less than that attainable with straight lines. It appeared also that the velocity varied, roughly speaking, with the radius of curvature. Thus in any portion of a curve which approached to the straight line the velocity was comparatively rapid, while in those of small radius it was decidedly less so (Series D.). I found also that where a curvilinear figure, elliptical or circular, was drawn, the velocity was less than in the simple curved line. The portion of the curve in the long axis of an ellipse was more rapidly drawn than that in the short axis, and in the only approximately circular figures (plates E_1, E_2) which I was able to draw at high speed, the velocity was least of all. I then examined a few specimens of my writing, at first at ordinary speed (F_1), and then

as fast as I could write (F2 – F5). The same observations were found to apply to these. The rectilinear parts of the letters were more rapidly drawn than the turns. In capital letters a higher velocity was attained than in small letters, except in those with tails where a long line was possible (F1, F4, F5). It was also seen, for instance in the capital Ps of (F2), that the middle portion of a straight line had a higher velocity than the beginning or end of it.

After these preliminary experiments, I proceeded to conduct a similar series upon other subjects. Those who were selected for this purpose belonged to various classes and professions. The list is as follows: –

1	medical practitioner,	aged 27
2	students	20, 24
1	stockbroker	27
1	pianist	24
1	organist	33
1	violinist	42
1	violoncellist	33
1	professor	59
1	lady	55
1	teacher of art	40
3	domestic servants	18, 24, 50.
2	ship's firemen	27, 41
3	labourers	36, 46, 62.
1	miner	27
1	engine fitter	36
1	ironworker	50
1	engineer	21

1 machineworker aged 27

1 storeman 36,

in all twenty-five cases, drawn from various classes of healthy individuals, the ages varying from 18 to 62. Analysis of the results shows very marked differences in the different cases, as will be seen from the details that follow. At this stage I found it advisable, as the speed over a distance of 3 cm. was not uniform, to measure also the length of the longest wave in each tracing, this giving, for each case, the distance passed over at maximum velocity in $\frac{1}{117}$". I found, in a general way, that the results were in accordance with what one would expect to be the case. The influence of age was distinctly noticeable. In those whose manual training was as nearly as possible equal, the rapidity was greater in the young than in the old. Unfortunately I have no case of extreme old age or of childhood to show, but in my oldest case, aged 62, the subject had suffered from chronic bronchitis for five years, and was quite grey-haired, and in other respects presented senile characteristics; while I have two tracings from a boy of 18, whom I have not included in the above list because he was epileptic, although neither his intelligence nor his muscular power were notably deficient, and the number of fits had been much lessened under hospital treatment. The majority of my cases from the uneducated classes were taken from convalescent patients in the skin and medical wards of the Western Infirmary, in whom practically no deviation from the normal condition existed. They were habituated, in their occupations, to coarse movements of the hands and arms, but the movements of their fingers were in no way trained; and although they were, without exception, able

to write, their correspondence, as may be supposed, was extremely infrequent. The others, three in number, were of the female sex, and were domestic servants. The rest were drawn from the educated classes. Of these, four males had no special training of the fingers, beyond what is given by comparatively frequent writing. Two, a lady aged 55, and myself, played the piano to a certain extent, the lady fairly well, though neither was in any sense a musician. Four were professional musicians, whose hands had been specially trained to the violin, violoncello, and piano, and one was a teacher of the fine arts, whose hands, therefore, were versed in drawing. Viewed from this standpoint of occupation, the results corresponded to a certain extent, as in the case of age, with what was to be expected. Those whose fingers were the least trained had the slowest movements, while the rate of movement increased in proportion to the education of the fingers. The relation of the velocity of the right hand to that of the left was also investigated.

The detailed results are as follows:—

1. <u>W. R. J., aet. 27</u> medical practitioner; thin, and general musculature rather poorly developed. Fingers of both hands used almost equally frequently, except in writing. A certain amount of practice on the piano.

Time occupied in covering space of 3 cm., pen-movement (Series A and B):-
Right hand:- $6\frac{1}{2}, 6, 8\frac{1}{2}, 5, 4\frac{1}{2}, 6, 9, 9, 7\frac{1}{2}, 6, 6\frac{1}{2}, 7\frac{1}{2}, 8, 7\frac{1}{2}, 8\frac{1}{2}, 5\frac{1}{2}, 8, 8, 9, 6\frac{1}{2}, 7, 7, 5, 6, 7\frac{1}{2}, 7, 5\frac{1}{2}, 4, 4\frac{1}{2}, 6, 4, 4, 5, 3, 5, 4, 4\frac{1}{2}, 3\frac{1}{2}, 3\frac{1}{2}, 5, 5, 5\frac{1}{2}, 4\frac{1}{2}, 4\frac{1}{2}, 7, 5, 5\frac{1}{2}, 5, 5, 3$. 50 tracings: average velocity $\frac{5\cdot9}{117}$"; average of last 25 (series B), comparable with those of left hand, as taken after a similar amount of practice, $\frac{4\cdot7}{117}$"; greatest velocity $\frac{3}{117}$"; greatest wave-length 11·5 mm.

Left hand (series C):- $6\frac{1}{2}, 4\frac{1}{2}, 5\frac{1}{2}, 5, 5, 3\frac{1}{2}, 4, 3, 4\frac{1}{2}, 6, 5, 4, 8, 4, 5, 4\frac{1}{2}, 3\frac{1}{2}$. 17 tracings:

average velocity $\frac{4.8}{117}$", greatest velocity $\frac{3}{117}$", greatest wave-length 11 mm.

Single twitch from one finger, carrying a needle-point:—

First finger of right hand, movement of flexion (series G):- 2, 2½, 1½, 1½, 1½, 1½, 1½, 2½, 2, 1½, 2, 2, 1½. 13 tracings, average velocity $\frac{1.8}{117}$", greatest velocity $\frac{1.8}{117}$", greatest wave-length, 19 mm.

First finger, R.H., movement of extension (series H):- 2, 2½, 2½, 2½ (three lines in middle of H1 and H3 run together, and not counted), 2, 1½, 2, 2½, 2, 2½, 2. 11 tracings: average velocity $\frac{2.2}{117}$", greatest velocity $\frac{1.8}{117}$", greatest wave-length 18 mm.

Second finger, R.H., flexion (plate I1):— 2, 2, 2½, 2. Average velocity $\frac{2.1}{117}$", greatest velocity $\frac{2}{117}$", greatest wave-length 19 mm.

Second finger, L.H., flexion (plate I2):- 2, 2, 2½, 2½, 2. Average velocity $\frac{2.2}{117}$", greatest velocity $\frac{2}{117}$", greatest wave-length 17 mm.

These series show very well the marked difference between the velocity of movement when several groups of muscles are in associated action, as when the pen-movement is made, and that of a single twitch from one small group, as in the flexion or extension of a single finger. It will be noted also that in this instance the average velocity of the movement of flexion is slightly greater than that of extension, and that the tracings from the second fingers of the right and left hand show a nearly identical velocity. These points will receive further attention in subsequent tracings.

Curved lines (series D):- (Only a few of the curves are here measured, as in drawing them rapidly it was impossible to keep them of the same length or radius. They are marked by a × on the plates.)

D1, chord of curve 22.5 mm. long, curvature slight, $\frac{13}{117}$". D2, chord of curve 17 mm. long, curvature somewhat greater, $\frac{15}{117}$"; D3, chord 55 mm. long, curved passing almost into straight line, $\frac{28}{117}$": more curved

portion, 20 mm. long, $\frac{16}{117}$" : rectilinear portion, 30 mm. long, $\frac{12}{117}$". D4, chord 44 mm. long, curvature slight $\frac{16}{117}$", the central portion here also being almost a straight line. D5 shows similar features.

Elliptical and circular figures :— E1; nearly closed ellipse, long axis 44 mm., short axis 19 mm. In middle of long axis 10 mm. covered in $\frac{5\frac{1}{2}}{117}$", at end of it, in $\frac{9}{117}$". The smaller figure shows similar features. E2; nearly circular figure, long diameter 8 mm., short diameter 6 mm. Velocity fairly uniform throughout, whole time occupied $\frac{26}{117}$".

Writing (series F; F1 at ordinary pace). It is apparent from (F1) that the parts of the letters and figures which are rectilinear are much more rapidly drawn than those which are curved, and that in curved portions the speed lessens with the space in which the turn must be made. Compare, for instance, the 'i' in 'eighth' with the 'g' in '1892'. The other tracings (F2 - F6), were taken as fast as I could write them, and bear out the above statement. In F3, for example, 1 cm. of the tail of the 'y' on the top line was drawn in $\frac{7}{117}$"; in the 'S' on the third line a curve with a chord of the same length was drawn in $\frac{17}{117}$".

The study, then, of the few curved lines and figures here presented as examples of many, prepares us for the peculiarities shown by writing. It must be remembered that as these figures were drawn at high speed, it was impossible to preserve uniformity of curvature, so that in many figures where I wished to obtain a great degree of curvature, the line may be in part of its course but little curved. One must compare then only portions of the curves in order to notice the difference, which the same line may show, that follows upon change of curvature. It amounts

to this, that the heighest velocity is attained in the straight line, or for small distances approximately straight line, produced by the natural sweep of the fingers in the pen-movement, and that any modification of this sweep entails a diminution of velocity which increases as the natural movement is departed from. The variations in speed in ordinary writing are seen to be very great.

I now pass to the results derived from other subjects.

2. A.A.J. aet. 24, student of law: of good physique, muscles fairly developed. No special training of hands. Writes much.

Pen-movement, R.H. (plate J1), 2, 3½. Greatest velocity $\frac{2}{117}$", greatest wave-length 14 mm. The two other tracings are incomplete.

Pen-movement, L.H. (plate J2), 3½, 3½, 3½. Other tracings incomplete. Greatest velocity $\frac{3{\cdot}5}{117}$", greatest wave-length 10 mm.

Single twitch, second finger, R.H. (plate J3), 2½, 2, 2½. Greatest velocity $\frac{2}{117}$", greatest wave-length 15 mm.

Single twitch, second finger, L.H. (plate J4) 2, 2½, 2½. Other tracings incomplete. Greatest velocity $\frac{2}{117}$", greatest wave-length 15 mm.

Writing. In this series of plates I endeavoured to make the subjects write letters as nearly as possible of the same length, for the sake of comparison, in ruled spaces 1 cm. apart. At high speed it was impossible to get more than an approximate equality. Plate J5:- straight part of the 'n' in line 4, 1 cm. long, $\frac{12}{117}$". curve of the 'o', chord of curve 8 mm. long, $\frac{17}{117}$".

It will be noted in the above series that, although the subject was not ambidextrous, there is no difference in the velocity of the single twitch in the right and left hand, but a noticeable difference in the velocity of the pen-movements, in favour of the right hand.

3. A.B., aet. 59, professor at the University; of good physique, muscles fairly developed. No special training of fingers.

Pen-movement, right hand (plate K 1), 4, 3½, 3½, 3½, 4½. Greatest velocity $\frac{3.5''}{117}$, greatest wave-length 10 mm.

Pen-movement, L.H. (plate K 2) 4½, 5, 4: lines much run together. Greatest velocity $\frac{4}{117}''$, greatest wave-length 10 mm.

Writing (plate K 3):- straight lines of the "n" in second line, 8 and 7.5 mm. long, $\frac{14}{117}''$ and $\frac{14}{117}''$.

In this and the following cases not all the tracings have been preserved, but only those that show the maximum velocity attained by the subject.

4. D.S., aet. 27, stockbroker; healthy and fairly muscular. No special training of fingers.

Pen-movement, R.H. (plate L 1), 3½, 3½. Other tracings incomplete. Greatest velocity $\frac{3.5''}{117}$, greatest wave-length 10 mm.

Finger movements: second finger R.H. (plate L 2), 2, 2½, 2. Greatest velocity $\frac{2}{117}''$, greatest wave-length 16 mm.

Second finger, L.H. (plate L 3), 2.2. Greatest velocity $\frac{2}{117}''$, greatest wave-length 16 mm.

Writing (plate L 4), line 3, second straight line of "n", 8 mm. long $\frac{10}{117}''$.

5. W.J.H.S., aet. 20, student, muscular and athletic. No special training of fingers.

Pen-movement, R.H. (plate M 1), 3½, 2, 2. Greatest velocity $\frac{2}{117}''$, greatest wave-length 17 mm.

Pen-movement, L.H. (plate M 2), 4, 5, 5. Greatest velocity $\frac{4}{117}''$, greatest wave-length 9 mm.

Finger movements; second finger, R.H. (plate M 3), 2, 3, 3. Greatest velocity $\frac{2}{117}''$, greatest wave-length 16 mm.

Second finger, L.H. (plate M 4), 2, 2½, 2, 3. Greatest velocity $\frac{2}{117}''$, greatest wave-length 18 mm. There may have been some pressure in all these curves, as in none is the line

quite regular.

Writing (plate M5), last straight line of the "n" in line 4, 10·5 mm. long, $\frac{7}{117}$".

6. M. S., aet. 18, female, domestic servant; healthy, but with a slight tendency to chlorosis. Writes a good hand, but does not write very frequently.

Pen-movement, R.H. (plate N1), 3, 10, 4, 4, 5. Greatest velocity $\frac{3}{117}$", greatest wave-length 12 mm.

Pen-movement, L.H. (plate N2), 7, 5, 8, 6. Greatest velocity $\frac{2}{117}$", greatest wave-length 9 mm.

Writing (plate N3); length of figure "1" in "1893" 10 mm., time occupied $\frac{11}{117}$".

7. M. Mc D., aet. 24, female, domestic servant; strong and healthy.

Pen-movement, R.H. (plate O1), 3½, 2½, 2. Greatest velocity $\frac{2}{117}$", greatest wave-length 16 mm.

Pen-movement, L.H. (plate O2), 3, 2½. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 14 mm.

8. J. C., aet. 50, female, domestic servant; looks older than her years, and is sometimes subject to muscular rheumatism. Writes very little, and with difficulty.

Pen-movement, R.H. (plate P), 5, 11, 8, 10. Greatest velocity $\frac{2}{117}$", greatest wave-length 7 mm.

I was unable to obtain a satisfactory tracing from her left hand, owing to her awkwardness in using it; nor would she give me a tracing of her writing.

9. Y. Z., aet. 33, a lady; somewhat 'delicate', but in good health at the time of the observation. Plays the piano a good deal, and has much correspondence.

Pen-movement, R.H. (plates Q1, Q2), 3, 3, 4, 2½, 3, 4, 3½, 3½. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 14 mm.

Pen-movement, L.H. (plate Q3), 3½. Greatest velocity $\frac{3·0}{117}$", greatest wave-length 11 mm.

Writing (plate Q4); first straight line of "n" in line 2, 10 mm. long, $\frac{20}{117}$".

10. T. H., aet. 24, male, vigorously built, muscles well-developed. Is one of the best-known pianists in Glasgow.

Finger-movements; first finger, R.H. (plate R1), 2½, 2, 1½. Greatest velocity $\frac{1·5}{117}$", greatest wave-length 19 mm.

Second finger, R.H. (plate R2), 1, 1½, 1½. Greatest velocity $\frac{1}{117}$", greatest wave-length 30 mm.

Third finger, R.H. (plate R3), 2,2,2. Greatest velocity $\frac{2}{117}$", greatest wave-length 17·5 mm.
Fourth finger, R.H. (plate R4), 2½, 2. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 15 mm.
First finger, L.H. (plate R5), 1½, 1¼. Greatest velocity $\frac{1·25}{117}$", greatest wave-length 27 mm.
Second finger, L.H. (plate R6), 2, 3, 2½. Greatest velocity $\frac{2}{117}$", greatest wave-length 17 mm.
Third finger, L.H. (plate R7), 3½, 2½. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 12 mm.
Fourth finger, L.H. (plate R8) 3, and nearly 2. Greatest velocity $\frac{2}{117}$", greatest wave-length 15 mm.
The tracings taken from the fourth finger are not of much value, owing to the cramped position in which the hand has to be held in their production.
Writing (plate R 9); first straight line of the "H" in line 2, 11 mm. long, $\frac{13}{117}$".

11. W.J.H., act. 33, brother of the preceding; of slighter build, but also of good physique. Is a well-known organist and teacher of the piano, but has not so much brilliancy of execution as his brother.
Finger-movements; first finger, R.H. (plate S1) 2, 2½. Greatest velocity $\frac{2}{117}$", greatest wave-length 18 mm.
Second finger, R.H. (plate S2), 2½, 1½, 2. Greatest velocity $\frac{1·5}{117}$", greatest wave-length 20 mm.
Third finger, R.H. (plate S3), 2½, 2½, 3½. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 12 mm.
The fourth finger was not examined.
First finger, L.H. (plate S4), 2, 2½, 2. Greatest velocity $\frac{2}{117}$", greatest wave-length 16 mm.
Second finger, L.H. (plate S5), 2, 2½, 2. Greatest velocity $\frac{2}{117}$", greatest wave-length 15 mm.
The third and fourth fingers were not examined, nor was the writing.

12. — D., act. 42, male, healthy and well-built. Is a professional violinist, in whom, consequently, the fingers of the left hand have received special education.
Finger-movements:- second finger, R.H. (plate T1), 3, 3½, 3. Greatest velocity $\frac{3}{117}$", greatest wave-length 11 mm.
First finger, L.H. (plate T2), 3, 4, 5. Greatest velocity $\frac{3}{117}$", greatest wave-length 11 mm.
Second finger, L.H. (plate T3), 2½, 3, 3½. Greatest velocity $\frac{2·5}{117}$", greatest wave-length 13 mm.
Third finger, L.H. (plates T4, T5), 4, 3½, 3½, 3½. Greatest velocity $\frac{3·5}{117}$", greatest wave-length 10·5 mm.
Fourth finger, L.H. (plate T6). Greatest velocity $\frac{4}{117}$", greatest wave-length 8 mm.

Writing (plate T 7); first descending line of "h" in line 4, 10 mm. long, $\frac{14}{117}$"

13. — A, aet. 33, male, of average development. Is a professional violoncellist, and, like the above subjects, the fingers of the left hand have had special education. He also plays the guitar, and thus exercises the fingers of his right hand in a plucking movement.

Finger-movements; second finger R.H. (plate U 1), 2, 2, 1½, 2. Greatest velocity $\frac{1{\cdot}5"}{117}$, greatest wave-length 21 mm.

First finger, L.H. (plate U 2), 2½, 2, 2, 2½. Greatest velocity $\frac{2"}{117}$, greatest wave-length 18 mm.

Second finger, L.H. (plate U 3), 1½, 1½, 1½, 2½. Greatest velocity $\frac{1{\cdot}5"}{117}$, greatest wave-length 19 mm.

Third finger, L.H. (plate U 4), 2½, 2½, 4½. Greatest velocity $\frac{2{\cdot}5"}{117}$, greatest wave-length 14 mm.

Fourth finger, L.H. (plate U 5), 2, 1½, 2. Greatest velocity $\frac{1{\cdot}5"}{117}$, greatest wave-length 22 mm.

14. L.R.C. aet. 40, male, teacher of technical art; healthy and solidly built. Has exercised his hands during many years in drawing and painting.

Finger-movements; second finger, R.H. (plate V 1), 2½, 2½, 2, 3, 3, 3, 3, Greatest velocity $\frac{2"}{117}$, greatest wave-length 15 mm.

Writing (plate V 2); first descending line of "h" in line 3, 12 mm. long, $\frac{12}{117}$".

Having thus stated the figures found in tracings obtained from those whose occupation or education involved an average amount of education of the fingers, and from those in whom excellence in their profession demanded an exceptional amount of such education, I pass to consider the tracings obtained from healthy men of the working classes, in whom the education of the fingers to perform fine movements is much below the average. These subjects, as before mentioned, were taken from the skin and medical wards of the Western Infirmary, and were for the most part convalescent from the diseases for which they had been admitted, and not in any way constitutionally enfeebled, except where it is expressly mentioned that such was the case. They may therefore be regarded as healthy subjects.

15. W. J. aet. 26, Labourer; admitted in the early stages of secondary syphilis, but now convalescent.

Pen. movement, R.H. (plate W1), 2½, 4½, 2½, 3. Greatest velocity $\frac{2.5"}{117}$, greatest wave-length 15 mm.
Pen. movement, L.H. (plates W2, W3), 5, 5, 5, 4, 4½, 4½, 6. Greatest velocity $\frac{4"}{117}$, greatest wave-length 9 mm.
Finger-movements; first finger, R.H. (W4), 2, 2½. Greatest velocity $\frac{2"}{117}$, greatest wave-length 16 mm.
Second finger, R.H. (W5), 2½, 2½, 2. Greatest velocity $\frac{2"}{117}$, greatest wave-length 16 mm.
Third finger, R.H. (W6) 3½, 3½, 3. Greatest velocity $\frac{3"}{117}$, greatest wave-length 12 mm.
First finger, L.H. (W7) 3, 2. Greatest velocity $\frac{2"}{117}$, greatest wave-length 17 mm.
Flexion and extension, first finger, R.H. (W8). Movement of flexion $\frac{2.5"}{117}$, greatest wave-length 12 mm., movement of extension $\frac{2.5"}{117}$, greatest wave-length 12 mm.
Writing (W9):— First upward stroke of the "h" in line 3 (only 7 mm. can be counted) $\frac{19"}{117}$.

16. J. McO., aet. 46, Labourer. This was a case from the medical wards. He had had mitral regurgitation for some time, and was admitted on account of cardiac symptoms, which disappeared under treatment. When the observations were made, he was able for ordinary exertion.

Pen-movement, R.H. (X1):— greatest velocity $\frac{3.5"}{117}$, greatest wave-length 10 mm.
Pen-movement, L.H. (X2), 9½, 10½, 5. Greatest velocity $\frac{5"}{117}$, greatest wave-length 8 mm.
Finger-movements; first finger R.H. (X3):- Greatest velocity $\frac{3.5"}{117}$, greatest wave-length 10 mm.
Second finger, R.H. (X4), 2½, 4, 2½. Greatest velocity $\frac{2.5"}{117}$, greatest wave-length 13 mm.
Movement of flexion $\frac{4"}{117}$, greatest wave-length 9 mm.; movement of extension $\frac{4.5"}{117}$, greatest wave-length 8 mm. (plate X5).
Writing (X6):- second descending line of "h" in 3rd line (only 7 mm. can be counted) $\frac{27"}{117}$

17. J. J., aet. 27, shirt fireman. Convalescent from secondary syphilis.

Pen-movement, R.H. (Y1), 2½, 3, 3½, 3½. Greatest velocity $\frac{2.5"}{117}$, greatest wave-length 14 mm.
Pen-movement, L.H. (Y2), 3½, 2, 3. Greatest velocity $\frac{2"}{117}$, greatest wave-length 18 mm.
Finger-movement; first finger R.H. (Y3 → Y4):- 2½, 3½, 2½, 2. Greatest velocity $\frac{2"}{117}$,

greatest wave-length 18 mm.

Movement of flexion (Y4) $\frac{2}{117}$", greatest wave-length 18 mm.; movement of extension $\frac{2.5}{117}$", greatest wave-length 15 mm.

Writing (Y5);— first descending line of "h" in line 2, 10 mm. long, $\frac{10}{117}$".

18. J. McN., aet. 21, engineer. Convalescent from an attack of eczema affecting the back and chest.

Pen-movement, R.H. (Z1), $2\frac{1}{2}, 3, 3, 3\frac{1}{2}, 3\frac{1}{2}$. Greatest velocity $\frac{2.5}{117}$", greatest wave-length 12 mm.

Pen-movement, L.H. (Z2, Z3), 3, 4, 3, 6, 4, 4, 4. Greatest velocity $\frac{3}{117}$", greatest wave-length 11 mm.

19. W.S., aet. 36, engine-fitter. Suffering from an attack of diabetes mellitus of about 3 months' duration. General health but little affected. Slight emaciation before admission, but improvement under treatment (sugar fell from 32·4 to 16 grs. per oz.).

Pen-movement, R.H. (AA1, AA2), $3\frac{1}{2}, 6\frac{1}{2}, 5, 3\frac{1}{2}, 4$. Greatest velocity $\frac{3.5}{117}$", greatest wave-length 11 mm.

Pen-movement, L.H. (plate AA3), 5, 5, $3\frac{1}{2}$. Greatest velocity $\frac{3.6}{117}$", greatest wave-length 10 mm.

Finger-movements; first finger, R.H. (AA4) $3, 2\frac{1}{2}, 3\frac{1}{2}$. Greatest velocity $\frac{2.5}{117}$", greatest wave-length 14 mm.

Second finger, R.H. (AA5), $2\frac{1}{2}, 2, 3$. Greatest velocity $\frac{2}{117}$", greatest wave-length 16 mm.

Third finger, R.H. (AA6), $4\frac{1}{2}, 3, 6$. " " $\frac{3}{117}$" " " " 11 mm.

First finger, L.H. (AA7), $3\frac{1}{2}, 2, 2\frac{1}{2}$ " " $\frac{2}{117}$" " " " 15 mm.

Second finger, L.H. (AA8), 5, 2, 3. " " $\frac{2}{117}$" " " " 15 mm.

Third finger, L.H. (AA9), 4, $3\frac{1}{2}$, $3\frac{1}{2}$. " " $\frac{3.5}{117}$" " " " 10 mm.

Movement of flexion (AA10);— velocity $\frac{4}{117}$", greatest wave-length 9 mm.; movement of extension;— velocity $\frac{5}{117}$", greatest wave-length 7 mm.

Writing (AA11);— first two descending lines of "m", line 4, 10 and 9 mm. long, $\frac{10}{117}$" and $\frac{17}{117}$".

20. J.C.D., aet. 36, stoneman. Admitted suffering from renal colic, which had quite disappeared when I took my observations. His initials

appear as J.C. on my plates, as I then imagined his compound name to be a single one.

Pen-movement, R.H. (BB1, BB2), 7½, 6, 4½, 3½. Greatest velocity $\frac{3.5}{117}$", greatest wave-length 10 mm.
Finger-movement; first finger, R.H (BB3), 3, 2, 5½, 5, 4. " " $\frac{2}{117}$" " " 19 mm.
Second finger, R.H. (BB4), 2½, 4, 3, 1½, 2, 2. " " $\frac{1.5}{117}$" " " 20 mm.
Third finger, R.H. (BB5), 2, 2½, 2, 3, 2, 2½. " " $\frac{2}{117}$" " " 17 mm.
Fourth finger, R.H. (BB6), 4½, 3, 3, 3, 3. " " $\frac{3}{117}$" " " 12 mm.
First finger, L.H. (BB7), 2, 3, 4, 3½. " " $\frac{2}{117}$" " " 17 mm.
Second finger, L.H. (BB8), 4, 4, 2½, 3½ " " $\frac{2.5}{117}$" " " 13 mm.
Third finger, L.H. (BB9), 3, 2½, 2, 4. " " $\frac{2}{117}$" " " 15 mm.
Fourth finger, L.H. (BB10), 6, 4½, 3, 3½ " " $\frac{3}{117}$" " " 12 mm.
Movement of flexion (BB11). " " $\frac{2}{117}$" " " 16 mm.
Movement of extension (BB11). " " $\frac{2.5}{117}$" " " 13 mm.

21. J.D., aet. 27, machine-worker; quite recovered from a slight attack of perityphlitis; nothing abnormal to be made out in the abdomen. Muscular and well-nourished.

Pen-movement, R.H. (CC1, CC2), 3½, 3½, 4½, 3, 3½, 5". Greatest velocity $\frac{3}{117}$", greatest wave-length 11 mm.

Writing (CC3); — first descending line of 'h' in line 1, 10 mm. long, $\frac{19}{117}$".

22. J.D. (no 2), aet. 27, miner (wrongly called 'grinder' on the slides. Admitted with an attack of pustular eczema; had always previously been healthy. Convalescent when tracings were taken.

Finger-movements, R.H., flexion (DD1, DD2); 2½, 2, 2½, 2½, 2, 2 (other tracings irregular). Greatest velocity $\frac{2}{117}$", greatest wave-length 18 mm.

Extension (DD3, DD4), 3, 2½, 2½, 3½, 3, 2½. Greatest velocity $\frac{2.5}{117}$", greatest wave-length 12 mm.

Left hand, flexion (DD5, DD6), 3, 2½, 2, 2½, 2, 2. " " $\frac{2}{117}$" " " 18 mm.

23. P.K., aet. 62, labourer. Suffering from chronic bronchitis and emphysema of 5 years' duration. Admitted with an aggravation of his symptoms,

but much improved by his stay in hospital. His age is stated at 60 on the slides, from what he told me, but in the journal it is given at 62. He looks older than he is, and obvious senile changes are present.

Pen. movement, R.H. (EE1, EE2), 6, 9½, 10, 14, 8, 7½. Greatest velocity $\frac{6}{117}$", greatest wave-length 6 mm.

First finger, R.H. (EE3), 6, 6, 7. " " $\frac{5}{117}$", " " 7 mm.

First finger, L.H. (EE4), 4½, 4. " " $\frac{4}{117}$", " " 9 mm.

Movement of flexion (EE5). " " $\frac{7}{117}$, " " 6 mm.

Movement of extension (EE5). " " $\frac{8}{117}$", " " 5 mm.

The two cases that follow are pathological.

24. <u>H. McQ., aet 50</u>, iron-worker; suffering from purpura haemorrhagica and constitutional syphilis. The purpura, when I saw him, had almost disappeared, but there was distinct tremor of both hands, and some contraction of the phalanges in the right hand. I could not find any exaggeration of reflexes, or any evidence of spasm or rigidity of muscles.

Pen. movement, R.H. (FF1 – FF3), 10½, 9, 5½, 7, 6, 7, 7, 8, 9, 9. Greatest velocity $\frac{5\cdot5}{117}$", greatest wave-length 6 mm.

Pen. movement, L.H. (FF4 – FF7), 10, 8, 9½, 9, 6, 6½, 5½, 12, 10, 7. " " $\frac{5\cdot5}{117}$", " " 7 mm.

First finger, R.H. (FF8), 6½, 4, 3. " " $\frac{3}{117}$", " " 13 mm.

Second finger, R.H. (FF9), 3, 2½, 3. " " $\frac{2\cdot5}{117}$" " " 13 mm.

25. <u>C.D., aet. 41</u>, ship's fireman. For twelve months before admission, had had tremor during walking, with spasms of the legs. No girdle-sensation or anaesthesia. Patellar reflexes exaggerated, and ankle-clonus present on both sides. Fundi normal. Occasional tremor or spasm of the hands. He also suffered from cystitis, which improved under treatment. Some time after I saw him, vomiting supervened, with rapid loss of strength, ending in death.

Pen. movement, R.H. (GG1), 11, 15, 23, 13. Greatest velocity $\frac{11}{117}$", greatest wave-length 4 mm.

Pen. movement, L.H. (GG2), 46, 50, 26. " " $\frac{25}{117}$" " " 2 mm.

First finger, R.H. (GG3), 7, 4½, 4½, 8, 7. " " $\frac{4\cdot5}{117}$" " " 12 mm.

Second finger, R.H. (GG4), 15, 14, 14½, 6. Greatest velocity $\frac{6}{117}$", greatest wave-length 7 mm.
Third finger, R.H. (GG5), 14, 10, 12. " " $\frac{10}{117}$", " " 4 mm.
First finger, L.H. (GG6), 13, 6, 13, 15. " " $\frac{6}{117}$", " " 6 mm.
Second finger, L.H. (GG7), 17, 18, 23. " " $\frac{17}{117}$", " " 3 mm.
Movement of flexion (GG8). " " $\frac{7.5}{117}$", " " 5 mm.
Movement of extension (GG8). " " $\frac{7.5}{117}$", " " 7 mm.
Writing (GG9) not to be measured by the naked eye.

Finally, in two tracings of the pen-movement taken from an epileptic boy, aged 15, whose intelligence did not seem appreciably impaired, nor his muscular power diminished, the greatest velocity for the right hand was $\frac{3}{117}$", and the greatest wave-length 12 mm., while for the left hand they were respectively $\frac{3}{117}$", and 10 mm. (HH1, HH2)

These are the figures obtained from my investigations with this instrument. Their relation to each other will be more easily understood by tabulation. For this purpose I shall divide the subjects into three classes; (1) those whose hands and fingers have undergone a special education, (2) those of average, and (3) those of inferior manual education. Domestic servants stand somewhere between the two latter, but perhaps nearer the second, with which I shall group them, than the third class. In class (1), the pen-movement was unfortunately not examined.

Class II. Pen-movement

	R. H.		L. H.	
	Vel.	Wave.	Vel.	Wave.
W.R.J.	$\frac{3}{117}$"	11·5 mm.	$\frac{3}{117}$"	11 mm.
A.H.J.	$\frac{2}{117}$"	14 mm.	$\frac{3.5}{117}$"	10 mm.
A.B.	$\frac{3.5}{117}$"	10 mm.	$\frac{4}{117}$"	10 mm.
D.S.	$\frac{3.5}{117}$"	10 mm.	—	—
W.J.H.S.	$\frac{2}{117}$"	17 mm.	$\frac{4}{117}$"	9 mm.

	R. H.		L. H.	
	Vel.	Wave.	Vel.	Wave.
M.S.	$\frac{3}{117}$"	12 mm.	$\frac{5}{117}$"	9 mm.
M. McD.	$\frac{2}{117}$"	16 mm.	$\frac{2.5}{117}$"	14 mm.
F.C.	$\frac{5}{117}$"	7 mm.	—	—
J.Z.	$\frac{2.5}{117}$"	14 mm.	$\frac{3}{117}$"	11 mm.
Average	$\frac{2.9}{117}$"	12·4 mm.	$\frac{3.6}{117}$"	10·6 mm.

Class III. Pen-movement.

	R. H.		L. H.	
	Vel.	Wave	Vel.	Wave
W.J.	$\frac{2.5"}{117}$	15 mm.	$\frac{4"}{117}$	9 mm.
J.McO.	$\frac{3.5"}{117}$	10 mm.	$\frac{5"}{117}$	8 mm.
J.J.	$\frac{2.5"}{117}$	14 mm.	$\frac{2"}{117}$	18 mm.
J.McH.	$\frac{2.5"}{117}$	12 mm.	$\frac{3"}{117}$	11 mm.
W.S.	$\frac{3.5"}{117}$	11 mm.	$\frac{3.5"}{117}$	10 mm.
J.C.D.	$\frac{3.5"}{117}$	10 mm.	—	—
J.D.	$\frac{3"}{117}$	11 mm.	—	—
J.D. no2.	—	—	—	—
P.K.	$\frac{6"}{117}$	6 mm.	—	—
Boy of 15 (not included in average)	$(\frac{3"}{117})$	(12 mm.)	$(\frac{3"}{117})$	(10 mm.)
Average: —	$\frac{3.4"}{117}$	11.1 mm.	$\frac{3.5"}{117}$	11.2 mm.

The two pathological cases will be dealt with separately.

We see from these tables:— (1) That in those of inferior manual education the velocity of pen-movements is equal in both hands; (2) That in those of average manual education, the velocity is greater in the right hand, which has been trained, than in the left, which has not; (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.

Finger-movements. Class I. Right hand.

	1st finger		2nd finger		3rd finger		4th finger	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
L.R.C.	—	—	$\frac{2"}{117}$	15 mm.	—	—	—	—
W.T.H.	$\frac{2"}{117}$	18 mm.	$\frac{1.5"}{117}$	20 mm.	$\frac{2.5"}{117}$	12 mm.	—	—
T.H.	$\frac{1.5"}{117}$	19 mm.	$\frac{1"}{117}$	30 mm.	$\frac{2"}{117}$	17.5 mm.	$\frac{2.5"}{117}$	15 mm.
—D.	—	—	$\frac{3"}{117}$	11 mm.	—	—	—	—
—A.	—	—	$\frac{1.5"}{117}$	21 mm.	—	—	—	—
Average: —	$\frac{1.75"}{117}$	18.5 mm.	$\frac{1.8"}{117}$	19.4 mm.	$\frac{2.25"}{117}$	15 mm.	$\frac{2.5"}{117}$	15 mm.

Finger-movements. Class I. Left hand.

	1st finger.		2nd finger.		3rd finger.		4th finger.	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
W.T.H.	$\frac{2}{117}$"	16 mm.	$\frac{2}{117}$"	15 mm.	—	—	—	—
T.H.	$\frac{1.25}{117}$"	27 mm.	$\frac{2}{117}$"	17 mm.	$\frac{2.5}{117}$"	12 mm.	$\frac{2}{117}$"	15 mm.
-D.	$\frac{3}{117}$"	11 mm.	$\frac{2.5}{117}$"	13 mm.	$\frac{3.5}{117}$"	10.5 mm.	$\frac{4}{117}$"	8 mm.
-A.	$\frac{2}{117}$"	18 mm.	$\frac{1.5}{117}$"	19 mm.	$\frac{2.5}{117}$"	14 mm.	$\frac{1.5}{117}$"	22 mm.
Average: —	$\frac{2.03}{117}$"	18 mm.	$\frac{2}{117}$"	16 mm.	$\frac{2.8}{117}$"	12.2 mm.	$\frac{2.5}{117}$"	15 mm.

Finger-movements. Class II. Right hand. Left hand.

	1st finger		2nd finger		1st finger		2nd finger	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
W.R.J.	$\frac{1.5}{117}$"	19 mm.	$\frac{2}{117}$"	19 mm.	—	—	$\frac{2}{117}$"	17 mm.
A.A.J.	—	—	$\frac{2}{117}$"	15 mm.	—	—	$\frac{2}{117}$"	15 mm.
D.S.	—	—	$\frac{2}{117}$"	16 mm.	—	—	$\frac{2}{117}$"	16 mm.
W.J.H.S.	—	—	$\frac{2}{117}$"	16 mm.	—	—	$\frac{2}{117}$"	18 mm.
Average: —	$\frac{1.5}{117}$"	19 mm.	$\frac{2}{117}$"	16.75 mm.	—	—	$\frac{2}{117}$"	16.5 mm.

The study of finger-movements was begun later than that of pen-movements, and, as most of the subjects in Class II were among the earlier observations, tracings of the finger-movements have been obtained from only a few of them.

Finger-movements. Class III. Right hand.

	1st finger		2nd finger		2nd finger		4th finger	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
W.S.	$\frac{2}{117}$"	16 mm.	$\frac{2}{117}$"	16 mm.	$\frac{3}{117}$"	12 mm.	—	—
S.McO.	$\frac{3.5}{117}$"	10 mm.	$\frac{2.5}{117}$"	13 mm.	—	—	—	—
S.J.	$\frac{2}{117}$"	18 mm.	—	—	—	—	—	—
W.S.	$\frac{2.5}{117}$"	14 mm.	$\frac{2}{117}$"	15 mm.	$\frac{3}{117}$"	11 mm.	—	—
S.C.D.	$\frac{2}{117}$"	19 mm.	$\frac{1.5}{117}$"	20 mm.	$\frac{2}{117}$"	17 mm.	$\frac{3}{117}$"	12 mm.
S.D.	$\frac{2}{117}$"	18 mm.	—	—	—	—	—	—
P.K.	$\frac{5}{117}$"	7 mm.	—	—	—	—	—	—
Average: —	$\frac{2.7}{117}$"	14.5 mm.	$\frac{2}{117}$"	16 mm	$\frac{2.6}{117}$"	13 mm.	$\frac{3}{117}$"	12 mm.

Finger. movements. Class III. Left hand.

	1st finger		2nd finger		3rd finger		4th finger	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
W.S.	2/117"	17 mm.	—	—	—	—	—	—
W.S.	2/117"	15 mm.	2/117"	15 mm.	3·5/117"	10 mm.	—	—
J.C.D.	2/117"	17 mm.	2·5/117"	13 mm.	2/117"	15 mm.	3/117"	12 mm.
J.D.	2/117"	18 mm.	—	—	—	—	—	—
P.K.	4/117"	9 mm.	—	—	—	—	—	—
	2·4/117"	15 mm.	2·2/117"	14 mm.	2·7/117"	12·5 mm.	3/117"	12 mm.

Comparing then the averages of the three classes, we have the following result:—

Right hand.

	1st finger		2nd finger		3rd finger		4th finger.	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
Class I	1·75/117"	18·5 mm.	1·8/117"	19·4 mm.	2·25/117"	15 mm.	2·5/117"	15 mm.
Class II	1·5/117"	19 mm.	2/117"	16·4 mm.	—	—	—	—
Class III	2·7/117" (2·3/117")	14·5 mm. (16 mm.)	2/117"	16 mm.	2·6/117"	13 mm.	3/117"	12 mm.

Left hand

	1st finger		2nd finger		3rd finger		4th finger	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
Class I	2/117"	18 mm.	2/117"	16 mm.	2·8/117"	12·2 mm.	2·5/117"	15 mm.
Class II	—	—	2/117"	16·5 mm.	—	—	—	—
Class III	2·4/117" (2/117")	15 mm. (16 mm.)	2·2/117"	14 mm.	2·7/117"	12·5 mm.	3/117"	12 mm.

If we leave out from Class III the tracings taken from P.K., who was much older than any of the other subjects, we have for the first finger the figures in brackets.

Comparing these figures, it becomes evident;— (1) That the velocity of movement varies in the different fingers. The velocity of the first and second fingers is approximately equal, and is noticeably greater than that of the third and fourth, which again are on a footing of approximate

equality; (2) That the velocity differs but little for the same finger of the different hands. The velocity of the second and fourth fingers of the right hand, for example, is practically identical with that of the same fingers of the left, while with regard to the first and third, the difference in favour of the right hand is exceedingly slight; (3) That the velocity for each finger is practically identical for all three classes, and that, in particular, special education does not appear to have conferred upon artists any definite advantage over the working classes; (4) That the velocity of the finger-movements as a whole is distinctly greater than that of the pen-movements.

Beside these tracings may be put, as they are comprised among finger-movements, a few made for the purpose of determining whether there were any noticeable difference in the speed of movements of flexion and of movements of extension. In some of these the movements of flexion were made upon one slide, and those of flexion upon another, while in the rest alternate movements were made upon the same slide.

	Flexion		Extension	
	Vel.	Wave.	Vel.	Wave.
W.R.J.	1·5" / 117	19 mm.	1·5" / 117	18 mm.
W.J.	2·5" / 117	12 mm.	2·5" / 117	12 mm.
J.McO.	4" / 117	9 mm.	4·5" / 117	8 mm.
J.D.	2" / 117	18 mm.	2·5" / 117	15 mm.
W.S.	4" / 117	9 mm.	5" / 117	7 mm.
J.C.D.	2" / 117	16 mm.	2·5" / 117	13 mm.
J.D. no 2.	2" / 117	18 mm.	2·5" / 117	12 mm.
P.K.	7" / 117	6 mm.	8" / 117	5 mm.
Average:—	3·1" / 117	13·5 mm.	3·8" / 117	11·25 mm.

There appears, then, to be a slight difference, in the fingers, in favour

of the greater rapidity of movements of flexion, which is shown both by the rate at which 3 cm. of the slide are covered, and by the greater wave-length. But in the two first cases the velocity over 3 cm. was absolutely identical, while there was a very slight difference in the greatest wave-length in favour of flexion.

In considering the results obtained from writing, as the length of the lines differed, in spite of my endeavour to obtain uniformity, I have thought it better to calculate out the velocities in each case for a length of 10 mm., to afford a basis of comparison. As I have already shown, from the plates of curved lines, and as is evident from a cursory inspection of the tracings of writing, that the velocity of a curve is less than that of a straight line, and varies, roughly speaking, as the radius of curvature, it is only necessary here to consider the velocities of the straight parts of the letters. I have measured in each case the maximum velocity. The following tables afford a survey of the results:—

Class I.		Class II.		Class III.	
T.H.	$\frac{11\cdot8}{117}$"	W.R.S.	$\frac{7}{117}$"	W.S.	$\frac{27\cdot1}{117}$"
-D.	$\frac{14}{117}$"	A.A.S.	$\frac{12}{117}$"	S.McO.	$\frac{36\cdot6}{117}$"
L.R.C.	$\frac{10}{117}$"	A.B.	$\frac{15\cdot7}{117}$"	S.T.	$\frac{10}{117}$"
Average:-	$\frac{12}{117}$"	D.S.	$\frac{15}{117}$"	W.S.	$\frac{18}{117}$"
		W.S.N.S.	$\frac{6\cdot6}{117}$"	S.D.	$\frac{19}{117}$"
		M.S.	$\frac{11}{117}$"	Average:-	$\frac{22\cdot5}{117}$"
		Y.Z.	$\frac{20}{117}$"		
		Average:-	$\frac{12\cdot5}{117}$"		

The average $\left(\frac{12}{117}"\right)$, then, for those with special manual education is practically the same as that for those with average manual education $\left(\frac{12\cdot5}{117}"\right)$. But the special education these artists have undergone has had no reference to writing. It has had to do with accelerating, strengthening, and lending

precision to the movements of the separate fingers. It is fair, then, in this regard to group these two classes as one, for the amounts of correspondence performed by each is probably nearly the same. Viewed in this way, a very marked contrast exists between them and the working classes, whose average is $\frac{22.5}{117}$", or nearly double that of the educated classes. We note also, on comparing the averages in the various kinds of movement, that the difference between education and the want of it is greatest in writing, much less in pen-movements, and scarcely noticeable in finger-movements. And we find that the average velocity for all classes is least in writing, much greater in a single pen-movement, and greatest in a single twitch of the finger. But the velocity diminishes as the complexity of the movement increases. It is in complex movements, therefore, that the greatest differences are found, and this is the reason for the at first sight astonishing uniformity of the results obtained from finger-movements. With appropriate instruments, it would, I have no doubt, be found that the fingers of the musician would be able to perform rapidly repeated movements with a far greater velocity than that attainable by any of the other classes. The more nearly the movement approaches a simple muscular twitch, the less is the influence of education observable.

I now pass to speak of the influence of age upon the velocity of the movements. For this purpose I shall divide the patients into classes according to the decade of life to which they belong, and further into educated and uneducated subjects, and I shall examine first the writing, then the pen-movements, and finally the finger-movements. The following table illustrates the influence of age upon the velocity of writing:—

	Educated.	Uneducated.
Under 20.		
M.S., aet. 18	$\frac{11}{117}$"	
From 20 to 29.		
W.S.N.S., aet. 20	$\frac{6.6}{117}$"	J.T., aet. 27 $\frac{10}{117}$"
T.H., aet. 24	$\frac{11.8}{117}$"	J.D., aet. 27 $\frac{19}{117}$"
A.A.T., aet. 24	$\frac{12}{117}$"	Average:- $\frac{14.5}{117}$"
W.R.J., aet. 27	$\frac{7}{117}$"	
Average:-	$\frac{9.35}{117}$"	
From 30 to 39.		
		W.J., aet. 36 $\frac{27.1}{117}$"
		W.S., aet. 36 $\frac{18}{117}$"
		Average:- $\frac{22.5}{117}$"
From 40 to 49.		
L.R.C., aet. 40	$\frac{10}{117}$"	
-D., aet. 42	$\frac{14}{117}$"	J.McO., aet. 46 $\frac{38.6}{117}$"
Average:-	$\frac{12.0}{117}$"	
From 50 to 59.		
Y.Z., aet. 55	$\frac{20}{117}$"	
A.B., aet. 59	$\frac{15}{117}$"	
Average:-	$\frac{17.5}{117}$"	

As far as these figures go, they seem to indicate a slowing of the velocity of writing, i.e. of the power to perform complicated movements, as age advances. The velocity is at its greatest between 20 and 29 years of age, and decreases with every decade thereafter, less obviously, however, in the educated than in the uneducated.

The next table shows the effect of age upon the velocity of the pen-movements:—

Educated.					Uneducated.				
	R. H.		L. H.			R. H.		L. H.	
Under 20	Vel.	Wave.	Vel.	Wave.		Vel.	Wave.	Vel.	Wave.
M.S., 18	$\frac{3}{117}$"	12 mm.	$\frac{5}{117}$"	9 mm.	Boy of 15.	$\frac{3}{117}$"	12 mm.	$\frac{3}{117}$"	10 mm.
From 20 to 29.									
W.J.N.S., 20	$\frac{3}{117}$"	17 mm.	$\frac{4}{117}$"	9 mm.					
A.A.J., 24	$\frac{3}{117}$"	14 mm.	$\frac{3.5}{117}$"	10 mm.					
M.McD., 24	$\frac{2}{117}$"	16 mm.	$\frac{2.5}{117}$"	14 mm.	J.McN., 21	$\frac{2.5}{117}$"	12 mm.	$\frac{3}{117}$"	11 mm.
D.S., 27	$\frac{3.5}{117}$"	10 mm.	—	—	J.T., 27	$\frac{2.5}{117}$"	14 mm.	$\frac{2}{117}$"	18 mm.
W.R.J., 27	$\frac{3}{117}$"	11·5 mm.	$\frac{3}{117}$"	11 mm.	J.D., 27	$\frac{3}{117}$"	11 mm.	—	—
Average:-	$\frac{2.5}{117}$"	13·7 mm.	$\frac{3.25}{117}$"	11 mm.	Average:-	$\frac{2.7}{117}$"	12·3 mm.	$\frac{2.5}{117}$"	14·5 mm.
From 30 to 39.									
					W.S., 36	$\frac{2.5}{117}$"	15 mm.	$\frac{4}{117}$"	9 mm.
					W.S., 36	$\frac{3.5}{117}$"	11 mm.	$\frac{3.5}{117}$"	10 mm.
					J.C.D., 36	$\frac{3.5}{117}$"	10 mm.	—	—
					Average:-	$\frac{3.2}{117}$"	12 mm.	$\frac{3.75}{117}$"	9·5 mm.
From 40 to 49.									
					J.McO., 46.	$\frac{3.5}{117}$"	10 mm.	$\frac{5}{117}$"	8 mm.
From 50 to 59.									
F.C., 50	$\frac{5}{117}$"	7 mm.	—	—					
G.A., 53	$\frac{2.5}{117}$"	14 mm.	$\frac{3}{117}$"	11 mm.					
A.B., 59	$\frac{3.5}{117}$"	10 mm.	$\frac{4}{117}$"	10 mm.					
	$\frac{3.7}{117}$"	10·3 mm.	$\frac{3.5}{117}$"	10·5 mm.					
Over 60.									
					P.R., 62	$\frac{6}{117}$"	6 mm.	—	—

From these tables it will be seen that there is in this case also a tendency to decrease of velocity with advancing years, greater in the uneducated, but that it is not so marked as in the case of the more complex movement of writing. The

velocity is nevertheless greatest between the ages of 20 and 29, precisely as in the case of writing.

Finger-movements.	1st finger.		2nd finger.		3rd finger.		4th finger.	
From 20 to 29	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
Educated class, R.H.								
W.J.H.S., 20	—	—	$\frac{2}{117}$"	16 mm.	—	—	—	—
J.H., 24.	$\frac{1.5}{117}$"	19 mm.	$\frac{1}{117}$"	30 mm.	$\frac{2}{117}$"	17.5 mm.	$\frac{2.5}{117}$"	15 mm.
A.A.S., 24.	—	—	$\frac{2}{117}$"	15 mm.	—	—	—	—
D.S., 27	—	—	$\frac{2}{117}$"	16 mm.	—	—	—	—
W.R.J., 27	$\frac{1.5}{117}$"	19 mm.	$\frac{2}{117}$"	19 mm.	—	—	—	—
Average:-	$\frac{1.5}{117}$"	19 mm.	$\frac{1.8}{117}$"	19 mm.	$\frac{2}{117}$"	17.5 mm.	$\frac{2.5}{117}$"	15 mm.
Educated class, L.H.								
W.J.H.S., 20.	—	—	$\frac{2}{117}$"	18 mm.	—	—	—	—
J.H., 24	$\frac{1.25}{117}$"	27 mm.	$\frac{2}{117}$"	17 mm.	$\frac{2.5}{117}$"	12 mm.	$\frac{2}{117}$"	15 mm.
A.A.S., 24	—	—	$\frac{2}{117}$"	15 mm.	—	—	—	—
D.S., 27	—	—	$\frac{2}{117}$"	16 mm.	—	—	—	—
W.R.J., 27	—	—	$\frac{2}{117}$"	17 mm.	—	—	—	—
Average:-	$\frac{1.25}{117}$"	27 mm.	$\frac{2}{117}$"	16.6 mm.	$\frac{2.5}{117}$"	12 mm.	$\frac{2}{117}$"	15 mm.
Uneducated class, R.H.								
J.J., 27	$\frac{2}{117}$"	18 mm.						
J.D., 27	$\frac{2}{117}$"	18 mm.						
Average:-	$\frac{2}{117}$"	18 mm.						
Uneducated class, L.H.								
J.D., 27	$\frac{2}{117}$"	18 mm.						
From 30 to 39.								
Educated class, R.H.								
W.J.H., 33	$\frac{2}{117}$"	18 mm.	$\frac{1.5}{117}$"	20 mm.	$\frac{2.5}{117}$"	12 mm.	—	—
- A., 33	—	—	$\frac{1.5}{117}$"	21 mm.	—	—	—	—
Average:-	$\frac{2}{117}$"	18 mm.	$\frac{1.5}{117}$"	20.5 mm.	$\frac{2.5}{117}$"	12 mm.	—	—

	1st finger.		2nd finger.		3rd finger.		4th finger.	
From 30 to 39.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
Educated class, L.H.								
W.J.H., 33.	$\frac{2}{117}$"	16 mm.	$\frac{2}{117}$"	15 mm.	—	—	—	—
– A., 33.	$\frac{2}{117}$"	18 mm.	$\frac{1.5}{117}$"	19 mm.	$\frac{2.5}{117}$"	14 mm.	$\frac{1.5}{117}$"	22 mm.
Average: –	$\frac{2}{117}$"	16 mm.	$\frac{1.75}{117}$"	17 mm.	$\frac{2.5}{117}$"	14 mm.	$\frac{1.5}{117}$"	22 mm.
Uneducated class, R.H.								
W. J., 36	$\frac{2}{117}$"	16 mm.	$\frac{2}{117}$"	16 mm.	$\frac{3}{117}$"	12 mm.	—	—
W.S., 36	$\frac{2.5}{117}$"	14 mm.	$\frac{2}{117}$"	15 mm.	$\frac{3}{117}$"	11 mm.	—	—
J.C.D., 36	$\frac{2}{117}$"	19 mm.	$\frac{1.5}{117}$"	20 mm.	$\frac{2}{117}$"	17 mm.	$\frac{3}{117}$"	12 mm.
Average: –	$\frac{2.1}{117}$"	16·3 mm.	$\frac{1.8}{117}$"	17 mm.	$\frac{2.7}{117}$"	13·3 mm.	$\frac{3}{117}$"	12 mm.
Uneducated class, L.H.								
W. J., 36	$\frac{2}{117}$"	17 mm.	—	—	—	—	—	—
W.S., 36	$\frac{2}{117}$"	15 mm.	$\frac{2}{117}$"	15 mm.	$\frac{3.5}{117}$"	10 mm.	—	—
J.C.D., 36	$\frac{2}{117}$"	17 mm.	$\frac{2.5}{117}$"	13 mm	$\frac{2}{117}$"	15 mm.	$\frac{3}{117}$"	12 mm.
Average: –	$\frac{2}{117}$"	16·3 mm.	$\frac{2.25}{117}$"	14 mm.	$\frac{2.75}{117}$"	12·5 mm.	$\frac{3}{117}$"	12 mm.
From 40 to 49.								
Educated class, R.H.								
L.R.C., 40	—	—	$\frac{2}{117}$"	15 mm.	—	—	—	—
– D., 42	—	—	$\frac{3}{117}$"	11 mm.	—	—	—	—
Average: –	—	—	$\frac{2.5}{117}$"	13 mm.	—	—	—	—
Educated class, L.H.								
– D., 42.	$\frac{3}{117}$"	11 mm.	$\frac{2.5}{117}$"	13 mm.	$\frac{3.5}{117}$"	10·5 mm.	$\frac{4}{117}$"	8 mm.
Uneducated class, R.H.								
J. McO., 46	$\frac{3.5}{117}$"	10 mm.	$\frac{2.5}{117}$"	13 mm.	—	—	—	—

Uneducated class, L.H., no tracing.

Over 50: uneducated class, R.H., P.K., 62.; first finger, $\frac{5}{117}$", 7 mm., L.H., first finger, $\frac{4}{117}$", 9 mm.

These tables indicate that the velocity of the finger-movements, the simplest of all, does not present anything like so marked a decrease with advancing age as in the other cases. It is practically the same for ages between 20 and 50, and the single tracing obtained from a man of 62 is not, of course, conclusive.

Before summarising the results obtained from a study of these cases, it may be well to compare them for a moment with the tracings derived from my two pathological cases.

	Vel.	Wave.
Pen-movement, R. H.		
C. D., 41.	$\frac{11}{117}$ "	4 mm.
H. McQ., 50	$\frac{5\cdot5}{117}$ "	6 mm.
Pen-movement, L. H.		
C. D.	$\frac{2\cdot5}{117}$ "	2 mm.
H. McQ.	$\frac{5\cdot5}{117}$ "	7 mm.

Finger-movement, R. H.	1st finger.		2nd finger.		3rd finger.	
	Vel.	Wave.	Vel.	Wave.	Vel.	Wave.
C. D.	$\frac{4\cdot5}{117}$ "	12 mm.	$\frac{6}{117}$ "	7 mm.	$\frac{10}{117}$ "	4 mm.
H. McQ.	$\frac{3}{117}$ "	13 mm.	$\frac{2\cdot5}{117}$ "	13 mm.	—	—
Finger-movement, L. H.						
C. D.	$\frac{6}{117}$ "	6 mm.	$\frac{17}{117}$ "	3 mm.	—	—

In the writing of C. D., the waves were so close together that they could not be counted by the naked eye.

These two cases of disease, then, as far as they go, support the deductions drawn from the normal cases. For we have the most complicated movements, (writing), most seriously retarded, while next come the pen-movements, and the finger-movements undergo the least retardation, being, in H. McQ., of nearly normal velocity.

We may now proceed to group together, and finally to summarise, the conclusions arrived at. With regard to the simple finger-movement, we find

that:—

(1) The velocity of movement is equal, or nearly so, in the first and second fingers, and is greater than that in the third and fourth, which have also nearly equal velocities. This may be due to the well-known arrangement of the tendon of the extensor communis digitorum passing to the third finger, and for the fourth finger, to the awkward position in which it was placed during the tracings.

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

(3) The velocity of the finger-movements is not appreciably affected by manual training.

(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.

(6) The velocity of the finger-movements remains nearly constant for ages between 20 and 30 (and thereafter probably declines, to judge from the isolated case of P.K.).

With regard to pen-movements we find that:—

(1) In those of inferior manual education, the velocity is equal in both hands.

(2) In the educated class, the velocity is greater in the educated right hand than in the comparatively uneducated left hand.

(3) The velocity in the right hand of the educated class is greater than that in the right hand of the uneducated class.

(4) The velocity in the uneducated left hand of the educated class is identical with that in the left hand of the uneducated class.

(5) The velocity of the pen-movements is more affected by age than that of the finger-movements, being greatest between the ages of 20 and 30.

With regard to writing, we find that:—

(1) The velocity of movements made in writing is less than that of the simple pen-movements.

(2) The velocity in the educated class is nearly double that in the uneducated class.

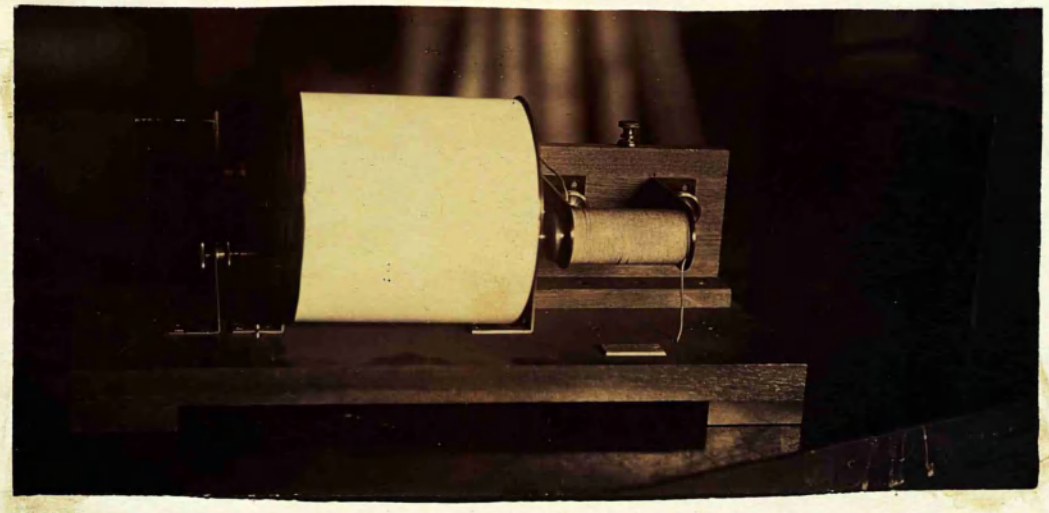
(3) The influence of age in retarding the velocity is quite marked. The velocity is greatest between the ages of 20 and 30, and diminishes with every succeeding decade.

(4) The velocity of the straight parts of letters is greater than that of the curved parts, and the velocity of a curve diminishes with the radius of curvature.

We find 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. While all classes are on an equality with regard to the finger-movement, which is as near a simple muscular twitch as one can come in the living body, the trained hand has a greater advantage over the untrained hand, the more complex is the movement that it has to perform. It is almost certain that this advantage would be equally obvious in the rapid repetition of a series of simple movements, but I have not investigated this subject. And as complex movements require a longer education for their rapid performance, so they appear to become sooner defective than the simpler movements. Thus it is in writing that the retarding effect of age is most apparent, while it is least so in the finger-movement.

I am aware that these conclusions are based upon too small a series of cases to warrant their general application, and that they may be modified in the light of further observations. I hope, as opportunity offers, to be able to continue what appears to me an interesting line of research. I have laid no stress upon the absolute velocities attained, for the reasons referred to at the beginning of this essay, but in their relation to one another these tracings afford a fair basis of comparison.

This concludes the first part of my subject.



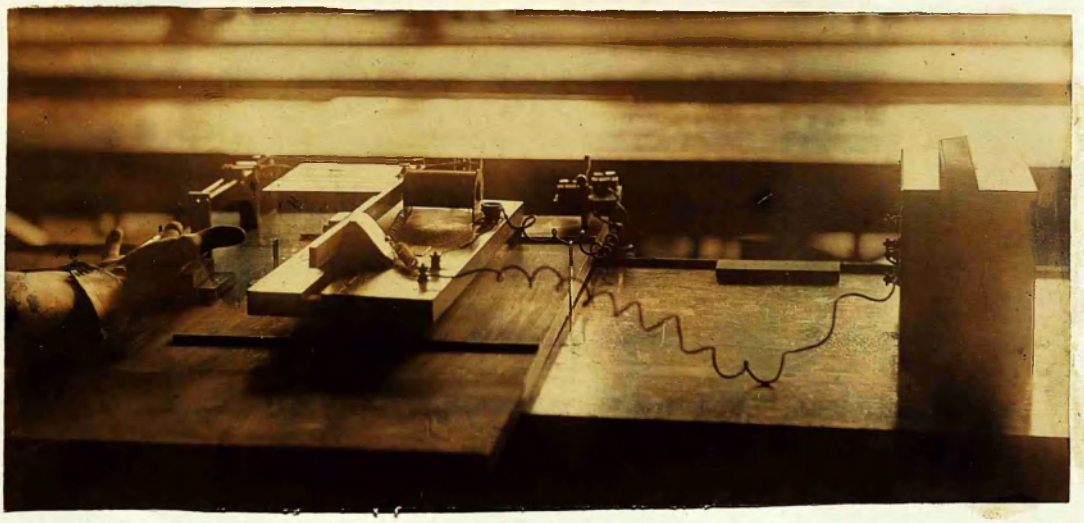
The plate is unfortunately too dark to show well the way in which the axle is balanced on the vertical springs, or the connection with the clockwork.

Part II.

At this point it occurred to me that it would be desirable to have tracings of a larger series of lines upon one plate than the microscopic slide could contain. I therefore suspended my experiments, and attempted to devise a suitable instrument, as the tuning-fork could not be driven with any considerable weight attached to it. In the endeavour I received the very kind assistance of Professor Mackendrick. He at first suggested a revolving drum, rotated in the ordinary way by clockwork, but having in addition a vibratory movement in the direction of its axis. After many trials, the instrument represented in the annexed photograph was produced. It consists essentially of a hollow brass cylinder made as light as possible, and carrying a roll of smoked paper. The axle had at one end a grooved wheel, which was connected with a similar wheel attached to the clockwork by an endless band. This furnished the rotatory movement. The vibratory movement was produced in the following way. At the other end of the axle was a soft iron keeper, which was placed in proximity to a strong electro-magnet, while the part of the axle between keeper and cylinder on the one side and wheel and cylinder on the other carried a groove which rested on the upper edges of two vertical brass springs. The current from five Grove's cells was used to produce the vibratory motion, and we at first attempted to provide for the make and break by interposing a Kronecker's spring in the circuit. But it was found that the vibration so obtained could not be made sufficiently rapid, for after a certain point it ceased to be uniform. We next tried, therefore, to increase the rate by shortening the springs on which the cylinder rested. For this purpose an ordinary platinum wire contact-breaker was attached to the spring furthest from the electro-magnet, wires being conducted to it under the

stage. This did away with the Kronecker's spring, and left the supporting springs free to vibrate at their own rate. But as they could not be shorter than the radius of the cylinder, the fastest vibration attainable was only 17 vibrations per second. This was too slow for my purpose, and I had to find some other instrument. But this one has since been found useful for other purposes by Dr Harris of this University.

I then abandoned the rotatory movement, and tried the effect of a single short brass spring, placed vertically, and carrying in a horizontal clip a broad plate of smoked glass. The vibration was more rapid, but its amplitude was so small as to be practically useless. At the third trial, with the aid of the mechanician, Mr Miller, of Ligars & Co., Glasgow, a satisfactory instrument was devised. It consists of a long steel bar, fastened in a short iron clamp which runs in a slot, so that various lengths of the bar can be used. At its shortest length (27·7 cm.) the bar, with all its loads, vibrates 54 times per second, as determined by chronographic tracings. It has a contact-breaker at the end opposite to the clamp, and is set in motion by an electromagnet, through which a current from two storage-cells passes. It carries a horizontal clamp, which holds a smoked glass plate, six inches square. I had intended to study the tracings derived from series of lines, but on seeing the instrument Professor Mackendrick suggested that it would be appropriate to the study of fatigue, and for this purpose it had to be somewhat amplified. The stage on which it was fixed was raised upon grooved wheels running on rails on a larger stage, to which an adaptation of Mosso's ergograph was attached. This consists of a disc of brass carrying a horizontal pointer, and having two holes traversed by parallel steel rods supported on brass pillars, while to either side of it a string is fastened. One



of these passes over a pulley and carries a weight which hangs free below the instrument; the other has a loop at the end to receive the middle finger. The first and third fingers are fixed in two parallel brass tubes, and the wrist is bound down by a leather collar, while the elbow is tied in so as to be incapable of backward movement. The only movement possible is that of the middle finger, which continuously pulls the weight up and lets it down again. The pointer records the tracing on the smoked plate, which is pulled away from it as uniformly as possible, vibrating at the same time under the influence of the electro-magnet. A key is interposed in the circuit, so that the current may be shut off at once while the plates are being changed, and turned on as soon as a fresh one is in place. The finger continues its work during the changing of the plates. The annexed photograph illustrates the apparatus.

The object of these tracings was to ascertain whether, besides the diminution in height of the fatigue contraction, there was also a diminution of velocity, and if so, whether the velocity were absolutely or only relatively less than that of the first contractions, i.e., whether the time occupied in covering the small contraction was or was not greater than that occupied in covering the large. The weights I used were ½ kilo., 1 kilo., and 2 kilo. When one plate was filled, it was slipped out from under the pointer, and quickly replaced by another, the finger continuing its work. The recording instrument was then run back close to the pointer, and after the current was turned on, it was slowly and regularly withdrawn.

In the first plates, I directed the subject to make the contractions succeed each other as rapidly as possible, but I found that the rapid relaxation this involved produced a swing and recoil of the suspended weight that very much confused the lines. Subsequently I asked for easy contraction and relaxation.

The first plates ($\bar{II}_1 - \bar{II}_3$) were taken from a young student, of about 20 years of age. The weight employed was 1 kilo. It will be seen how the recoil referred to has made the lines confused and irregular. These plates may be dismissed without further comment as failures for purposes of analysis.

The following tracings ($JJ_1 - LL$) were taken with a regular contraction and relaxation, and in them the confusion of lines is got rid of. They were taken from a robustly built student, aged about 25. In the series $JJ_1 - JJ_6$, a weight of ½ kilo. was used. There was an interval of one minute between successive tracings, which themselves occupied respectively 40", 45", 50", 45", 50", 40", 45" and 40 seconds, so that the whole period of work amounted to 14 min. 45 secs. Fatigue began to appear at the end of tracing 2 (JJ_2), 2 min. 30 secs. from the start, and increased throughout tracing 3 (4 min. 20 secs. from the start). Thereafter there was little appreciable difference in the length of the lines, even in tracing 9 (JJ_6). If we take in tracing 1 (JJ_1) the five contractions marked with a X, and measure their lengths and velocities, we find that:—

64 mm.	were covered in	$\frac{31}{54}$"
65 mm.	" " "	$\frac{33}{54}$"
64 mm.	" " "	$\frac{36}{54}$"
64 mm.	" " "	$\frac{31}{54}$"
66 mm.	" " "	$\frac{21}{54}$"
Average:- 64·6 mm.	" " "	$\frac{30·4}{54}$"

At the end of tracing 3 (JJ_3):—

46 mm.	were covered in	$\frac{27}{54}$"
44 mm.	" " "	$\frac{21}{54}$"
45 mm.	" " "	$\frac{26}{54}$"
45 mm.	" " "	$\frac{25}{54}$"
49 mm.	" " "	$\frac{30}{54}$"
Average:- 45·8 mm.	" " "	$\frac{25·8}{54}$"

At the end of tracing 9 (556), after 14½ minutes' work:—

35 mm.	were covered in	$\frac{22}{54}$"
38 mm.	" " "	$\frac{24}{54}$"
36 mm.	" " "	$\frac{17}{54}$"
36 mm.	" " "	$\frac{19}{54}$"
37 mm.	" " "	$\frac{19}{54}$"
Average:- 36·4 mm.	" " "	$\frac{20·2}{54}$"

There is thus in this case no absolute diminution of velocity from first to last. But if the initial velocity had been maintained 45·8 mm. ought to have been covered in $\frac{21·5}{54}$", and 36·4 mm. in $\frac{18·6}{54}$". Therefore there is a slight diminution in relative velocity. Comparing tracing 3 with tracing 9, however, we find that at the velocity of tracing 3 the 36·4 mm. of tracing 9 ought to have been covered in $\frac{20·5}{54}$", instead of the actual $\frac{20·2}{54}$". Therefore in the 10 min. 30 secs. elapsing between the two tracings there has been no change in the velocity of contraction.

The tracings taken with the 1 kilo. weight from the same subject are six in number. They occupied 30 secs. each, as nearly as possible, and the intervals between them were respectively 60, 40, 40, 35 and 45 secs. The whole duration of work was thus 6 min. 40 secs., and in that time, as will be seen from the heights of the contractions in tracing 6 (KK 5), much greater fatigue was produced than in the 14 mins. 45 secs. of the ½ kilo. weight. Fatigue began even in the first tracing, as is shown by the decrease in height, and continued to increase until the last, in which it will be noted how the finger appears to have lost control over its relaxation, and to be pulled rapidly down by the weight as soon as extension begins. The following table compares series of five contractions taken from tracings 1, 3, and 6.

Tracing 1 (KK 1).	Tracing 3 (KK 3).	Tracing 6 (KK 6).
56 mm. were covered in $\frac{20''}{54}$	32 mm. were covered in $\frac{19''}{54}$	24 mm. were covered in $\frac{19''}{54}$
55 mm. " " " $\frac{21''}{54}$	34 mm. " " " $\frac{16''}{54}$	25 mm. " " " $\frac{20''}{54}$
59 mm. " " " $\frac{22''}{54}$	35 mm. " " " $\frac{19''}{54}$	24 mm. " " " $\frac{20''}{54}$
53 mm. " " " $\frac{19''}{54}$	37 mm. " " " $\frac{21''}{54}$	21 mm. " " " $\frac{19''}{54}$
56 mm. " " " $\frac{21''}{54}$	35 mm. " " " $\frac{19''}{54}$	23 mm. " " " $\frac{20''}{54}$
56·2 mm. " " " $\frac{20·6''}{54}$	34·6 mm. " " " $\frac{18·8''}{54}$	23·2 mm. " " " $\frac{19·6''}{54}$

To maintain the velocity of tracing 1, that of tracing 3 should have been $\frac{12·6''}{54}$, and that of tracing 6 $\frac{8·5''}{54}$. To maintain that of tracing 3, that of tracing 6 should have been $\frac{12·9''}{54}$. There is thus a continuous decrease in relative velocity, and an absolute decrease, when tracing 6 is compared with tracing 3.

Plate LL gives two tracings from the same subject, with a weight of two kilos. Each lasted 1 min., and the interval was 40 secs. The rapid decline in the height of the contraction is beautifully shown at the end of tracing 1, and continues in tracing 2. I shall compare contractions at the beginning and end of tracing 1, and at the end of tracing 2.

Beginning of tracing 1.	End of tracing 1.	Tracing 2.
50 mm. were covered in $\frac{32''}{54}$	38 mm. were covered in $\frac{42''}{54}$	16 mm. were covered in $\frac{26''}{54}$
54 mm. " " " $\frac{28''}{54}$	37 mm. " " " $\frac{38''}{54}$	19 mm. " " " $\frac{25''}{54}$
57 mm. " " " $\frac{29''}{54}$	35 mm. " " " $\frac{33''}{54}$	15 mm. " " " $\frac{19''}{54}$
53 mm. " " " $\frac{27''}{54}$	34 mm. " " " $\frac{35''}{54}$	12 mm. " " " $\frac{15''}{54}$
53 mm. " " " $\frac{28''}{54}$	35 mm. " " " $\frac{30''}{54}$	15 mm. " " " $\frac{19''}{54}$
53·8 mm. " " " $\frac{28·8''}{54}$	35·8 mm. " " " $\frac{35·6''}{54}$	15·4 mm. " " " $\frac{21·4''}{54}$

At the rate of the beginning of tracing 1, that of the end of the tracing should be $\frac{19·1''}{54}$, and that of tracing 2 $\frac{8·2''}{54}$; while at the rate of the end of tracing 1, that of tracing 2 should be $\frac{15''}{54}$. Thus there is a continuous diminution of velocity, more rapid at the beginning of fatigue than after it has continued for some time. At the end of tracing 1 the absolute velocity

has diminished, i.e., it takes considerably longer to draw the shorter lines there than it did to draw the longer first contractions.

The next tracings (MM1 – MM5) are from a student aged 19, of fair physique. They were taken with a ½ kilo. weight. The tracings occupied respectively 25", 30, 30, and 25" secs., the time of the last unfortunately not being noted. It was probably about 30 secs. The intervals were 60, 60, 90, and 60 (?) secs. The whole observation therefore occupied 6½ to 7 mins. There is a marked difference in height between the first and second tracings, less between the second and third, and thereafter practically none. I shall examine contractions from the first, second, third, and last.

Tracing 1.

80 mm. were covered in	$\frac{21}{57}$"
74 mm. " " "	$\frac{16}{57}$"
79 mm. " " "	$\frac{19}{57}$"
74 mm. " " "	$\frac{16}{57}$"
73 mm. " " "	$\frac{17}{57}$"
76 mm. " " "	$\frac{17.4}{57}$"

Tracing 2.

44 mm. were covered in	$\frac{13}{57}$"
45 mm. " " "	$\frac{14}{57}$"
45 mm. " " "	$\frac{14}{57}$"
39 mm. " " "	$\frac{14}{57}$"
46 mm. " " "	$\frac{11}{57}$"
43·8 mm. " " "	$\frac{13.6}{57}$"

Tracing 3.

34 mm. were covered in	$\frac{10}{57}$"
32 mm. " " "	$\frac{10}{57}$"
30 mm. " " "	$\frac{11}{57}$"
29 mm. " " "	$\frac{10}{57}$"
28 mm. " " "	$\frac{9}{57}$"
30·6 mm. " " "	$\frac{10}{57}$"

Tracing 5.

29 mm. were covered in	$\frac{11}{57}$"
28 mm. " " "	$\frac{10}{57}$"
30 mm. " " "	$\frac{11}{57}$"
30 mm. " " "	$\frac{10}{57}$"
29 mm. " " "	$\frac{11}{57}$"
29·2 mm. " " "	$\frac{10.6}{57}$"

To maintain the rate of tracing 1, tracing 2 should have been covered in $\frac{10.0}{57}$", and tracing 3 in $\frac{7.0}{57}$". To maintain that of tracing 2, tracing 3 should have been covered in $\frac{9.6}{57}$", which is practically the case. Tracing 5 is nearly identical with tracing 3.

The next tracings (NN1 – NN4) are from the same subject, with a 1 kilo. weight

They occupied 25", 25", 35", 25", and 20 secs., and the intervals were 25", 30, 25", and 30 secs. The whole observation occupied 4 mins. There is a distinct drop between tracings 1 and 2, and 2 and 3. Subsequently it is less marked.

Tracing 1.

70 mm. were covered in	$\frac{24}{54}$"
72 mm. " " "	$\frac{19}{54}$"
72 mm. " " "	$\frac{24}{54}$"
70 mm. " " "	$\frac{20}{54}$"
76 mm. " " "	$\frac{31}{54}$"
73 mm. " " "	$\frac{21.6}{54}$"

Tracing 2.

34 mm. were covered in	$\frac{13}{54}$"
25 mm. " " "	$\frac{13}{54}$"
32 mm. " " "	$\frac{12}{54}$"
33 mm. " " "	$\frac{13}{54}$"
33 mm. " " "	$\frac{12}{54}$"
31.4 mm. " " "	$\frac{12.6}{54}$"

Tracing 3.

31 mm. were covered in	$\frac{12}{54}$"
29 mm. " " "	$\frac{14}{54}$"
30 mm. " " "	$\frac{12}{54}$"
29 mm. " " "	$\frac{11}{54}$"
27 mm. " " "	$\frac{14}{54}$"
29.2 mm. " " "	$\frac{12.6}{54}$"

Tracing 5.

23 mm. were covered in	$\frac{12}{54}$"
22 mm. " " "	$\frac{12}{54}$"
22 mm. " " "	$\frac{11}{54}$"
23 mm. " " "	$\frac{11}{54}$"
22 mm. " " "	$\frac{11}{54}$"
22.4 mm. " " "	$\frac{11.4}{54}$"

To maintain the velocity of tracing 1, tracing 2 should have been covered in $\frac{9.3}{54}$", tracing 3 in $\frac{8.7}{54}$", and tracing 5 in $\frac{6.6}{54}$". To maintain that of tracing 2, tracing 3 should have been covered in $\frac{11.7}{54}$", and tracing 5 in $\frac{9}{54}$". To maintain that of tracing 3, tracing 5 should have been covered in $\frac{9.7}{54}$" There is then a continuous, though not uniform, diminution of velocity.

The following tracings (001 – 005) are taken from a student aged 26, with a 1 kilo. weight. The velocities are small, for he pulled the ergograph very slowly, to avoid recoil. The tracings occupied 35", 30, 25", 25", 25", and 30 secs., the intervals 40, 45", 30, 30, and 20 secs., the whole experiment 5 mins. 35 secs. There is no obvious difference in height between tracings 1 and 2. Fatigue begins to be evident in the latter parts of 3, and is distinct in tracing 4, and

those following it. I shall take contractions from tracings 1, 4, and 6. The blurred part of the lines is not counted. I only include four contractions from tracing 1, as the fifth shows considerable diminution of velocity. In tracing 4, the instrument jarred somewhat, which accounts for the peculiar form of the waves in the latter half of the tracing.

Tracing 1.	Tracing 4.	Tracing 6.
73 mm. were covered in $\frac{31}{57}$"	45 mm. were covered in $\frac{16}{57}$"	27 mm. were covered in $\frac{20}{57}$"
73 mm. " " " $\frac{36}{57}$"	46 mm. " " " $\frac{24}{57}$"	27 mm. " " " $\frac{20}{57}$"
69 mm. " " " $\frac{36}{57}$"	36 mm. " " " $\frac{13}{57}$"	27 mm. " " " $\frac{20}{57}$"
72 mm. " " " $\frac{37}{57}$"	43 mm. " " " $\frac{17}{57}$"	27 mm. " " " $\frac{21}{57}$"
(72 mm. " " " $\frac{50}{57}$")	43 mm. " " " $\frac{23}{57}$"	24 mm. " " " $\frac{22}{57}$"
71·75 mm. " " " $\frac{35}{57}$"	42·6 mm. " " " $\frac{18·6}{57}$"	26·4 mm. " " " $\frac{20·6}{57}$"

To maintain the velocity of tracing 1, tracing 4 should have been covered in $\frac{20·8}{57}$". But it has been done somewhat faster ($\frac{18·6}{57}$"), so that in this case there is no decrease in velocity, although the height of the contraction is much diminished. Probably this is due to the subject's having begun the experiment at a rate below his natural speed. Tracing 6 should have been covered in $\frac{12·6}{57}$". There is then a considerable decrease in relative velocity, as compared with tracing 1, and a decrease in absolute velocity, as compared with tracing 4.

Plates PP1, PP2, were taken from the same student, with a weight of 2 kilos. Fatigue has begun to appear at the end of the first tracing, and is very marked in the others. The tracings occupied 40, 25, and 30 secs., the intervals 20 and 10 secs., the whole experiment therefore 2 min. 15 secs. I shall take contractions from all the tracings.

Beginning of tracing 1.	End of tracing 1.
50 mm. were covered in $\frac{40}{57}$"	23 mm. were covered in $\frac{27}{57}$"
50 mm. " " " $\frac{34}{57}$"	23 mm. " " " $\frac{21}{57}$"
	23 mm. " " " $\frac{21}{57}$"
50 mm. " " " $\frac{37}{57}$"	23 mm. " " " $\frac{23}{57}$"

Tracing 2.		Tracing 3.	
20 mm. were covered in	$\frac{25}{54}$"	16 mm. were covered in	$\frac{20}{54}$"
20 mm. " " "	$\frac{26}{54}$"	16 mm. " " "	$\frac{19}{54}$"
20 mm. " " "	$\frac{23}{54}$"	16 mm. " " "	$\frac{20}{54}$"
20 mm. " " "	$\frac{24.7}{54}$"	16 mm. " " "	$\frac{19.7}{54}$"

To maintain the initial velocity of tracing 1, that at the end of it should have been $\frac{17}{54}$", that of tracing 2 $\frac{14.8}{54}$", and that of tracing 3 $\frac{11.8}{54}$". To maintain the final velocity of tracing 1, tracing 2 should have been covered in $\frac{20}{54}$", and tracing 3 in $\frac{16}{54}$". To maintain that of tracing 2, tracing 3 should have been covered in $\frac{19.7}{54}$", as it actually is. There is thus a continuous decrease of velocity up to tracing 2, after which the velocity remains the same.

The two remaining cases are pathological. The first was a man aged 58, suffering from a slight attack of aphasia, with slight paresis of the arms and legs. Knee-jerks exaggerated; no ankle-clonus. The attack had followed on a series of convulsions lasting 36 hours, and affecting chiefly the left side. No anaesthesia or ataxy. Lungs slightly emphysematous; other organs normal. History of syphilis 3 years before. Some time after I saw him, a tumour appeared on the left side of the neck, which proved to be malignant. It increased rapidly, and caused some dyspnoea. He went alone into the bath-room one day, and was found there asphyxiated shortly after. P.M. revealed a cancer of the pancreas with infiltration of the psoas muscle, besides the tumour in the neck. There was no cortical lesion.

Plates QQ1, QQ2, show tracings taken with a 1 kilo. weight. The duration of the experiment was 3 min. 20 secs. Fatigue is manifest in the third tracing, about 2 min. 20 secs. from the start, and very apparent in the fourth. I shall consider contractions from the first, third, and fourth tracings.

Tracing 1.		Tracing 3.		Tracing 4.	
44 mm. were covered in	$\frac{13}{54}$"	35 mm. were covered in	$\frac{13}{54}$"	19 mm. were covered in	$\frac{9}{54}$"
44 mm. " " "	$\frac{13}{54}$"	29 mm. " " "	$\frac{15}{54}$"	19 mm. " " "	$\frac{10}{54}$"
45 mm. " " "	$\frac{15}{54}$"	31 mm. " " "	$\frac{14}{54}$"	15 mm. " " "	$\frac{9}{54}$"
46 mm. " " "	$\frac{14}{54}$"	35 mm. " " "	$\frac{13}{54}$"	13 mm. " " "	$\frac{9}{54}$"
45 mm. " " "	$\frac{14}{54}$"	33 mm. " " "	$\frac{14}{54}$"	20 mm. " " "	$\frac{13}{54}$"
224 mm. " " "	$\frac{13.8}{54}$"	32.6 mm. " " "	$\frac{13.8}{54}$"	17.2 mm. " " "	$\frac{10}{54}$"

To maintain the velocity of tracing 1, tracing 3 should have been covered in $\frac{10.1}{54}$", and tracing 4 in $\frac{5.3}{54}$". To maintain that of tracing 3, tracing 4 should have been covered in $\frac{7.3}{54}$". There is thus a continuous diminution of velocity.

Plate RR shows two tracings from the same subject, with a weight of 2 kilos. The experiment occupied 1 min. 30 secs. Fatigue is rapid, there being only 3 contractions in tracing 1 that are apparently free from it. I shall compare these with 3 from the end of the tracing, and 3 from tracing 2.

Beginning of tracing 1.		End of tracing 1.		Tracing 2.	
47 mm. were covered in	$\frac{25}{54}$"	30 mm. were covered in	$\frac{17}{24}$"	13 mm. were covered in	$\frac{10}{54}$"
50 mm. " " "	$\frac{24}{54}$"	31 mm. " " "	$\frac{16}{24}$"	13 mm. " " "	$\frac{10}{54}$"
50 mm. " " "	$\frac{26}{54}$"	29 mm. " " "	$\frac{19}{24}$"	11 mm. " " "	$\frac{10}{54}$"
49 mm. " " "	$\frac{25}{54}$"	30 mm. " " "	$\frac{17.3}{24}$"	12.3 mm. " " "	$\frac{10}{54}$"

To maintain the initial velocity of tracing 1, the end of it should have been covered at the rate of $\frac{15.3}{54}$", and tracing 2 at $\frac{6.3}{54}$". To maintain its final velocity, tracing 2 should have been covered in $\frac{7.1}{54}$". Thus there is a continuous diminution of velocity.

The next case is that of a man aged 32, suffering from locomotor ataxy of about four months' duration. The gait was characteristic. He had lightning pains, girdle-sensation, and numbness of the extremities. There were also incontinence and constipation. The eyes were normal, and the muscular

power was not diminished. The gait improved in hospital.

The tracings on plates SS1 – SS3 were taken with a weight of 1 kilo. The experiment lasted 4 min. 55 secs., and fatigue was not complete even at the end of it. I shall take contractions from tracings 1, 3, and 5.

Tracing 1.	Tracing 3.	Tracing 5.
57 mm. were covered in $\frac{28}{54}$"	38 mm. were covered in $\frac{13}{54}$"	40 mm. were covered in $\frac{10}{54}$"
51 mm. " " " $\frac{24}{54}$"	39 mm. " " " $\frac{11}{54}$"	40 mm. " " " $\frac{14}{54}$"
49 mm. " " " $\frac{29}{54}$"	44 mm. " " " $\frac{16}{54}$"	34 mm. " " " $\frac{15}{54}$"
52·3 mm. " " " $\frac{27}{54}$"	40·3 mm. " " " $\frac{13·3}{54}$"	38 mm. " " " $\frac{13}{54}$"

To maintain the velocity of tracing 1, tracing 3 should have a velocity of $\frac{20·9}{54}$". But it has a greater velocity, and tracing 5 is practically identical with it. Fatigue has not in this case led to diminution of the velocity.

Plate TT is from the same subject, with a 2 kilo. weight. At the end of tracing 2, fatigue is very obvious. The experiment lasted 1 min. 30 secs.

Tracing 1.	Tracing 2.
30 mm. were covered in $\frac{13}{54}$"	13 mm. were covered in $\frac{9}{54}$"
36 mm. " " " $\frac{17}{54}$"	12 mm. " " " $\frac{8}{54}$"
32 mm. " " " $\frac{15}{54}$"	16 mm. " " " $\frac{9}{54}$"
32 mm. " " " $\frac{19}{54}$"	16 mm. " " " $\frac{9}{54}$"
32·5 mm. " " " $\frac{16}{54}$"	14·25 mm. " " " $\frac{8·75}{54}$"

To maintain the velocity of tracing 1, tracing 2 should have a velocity of $\frac{7}{54}$", so that there has been a slight diminution of velocity over the two tracings.

I append a table bringing these results together, and showing, first the actual velocities in each case with each different weight, and second, what the velocities of the latter tracings should have been if the rate of tracing 1, tracing 2, &c., had been maintained. The approximate intervals between the contractions chosen are also mentioned.

Weight, ½ kilo.

Case I. 64·6 mm. $\frac{30\cdot4}{54}$" 4 min. interval 45·8 mm. $\frac{25\cdot8}{54}$" 10½ min. 36·4 mm. $\frac{20\cdot2}{54}$"

At rate of tracing I. $\frac{21\cdot5}{54}$" $\frac{18\cdot6}{54}$"

" " " " II $\frac{20\cdot5}{54}$"

Case II. 76·0 mm. $\frac{17\cdot4}{54}$" 1½ min. 43·8 mm. $\frac{13\cdot6}{54}$" 3½ min. 30·6 mm. $\frac{10}{54}$" 3½ min. 29·2 mm. $\frac{10\cdot6}{54}$"

At rate of tracing I $\frac{10\cdot0}{54}$" $\frac{7\cdot0}{54}$" $\frac{7\cdot0}{54}$"

" " " " II $\frac{9\cdot6}{54}$" $\frac{9\cdot6}{54}$"

" " " " III $\frac{10\cdot6}{54}$"

Weight 1 kilo.

Case I. 56·2 mm. $\frac{20\cdot6}{54}$" 2¾ min. 34·6 mm. $\frac{18\cdot8}{54}$" 3½ min. 23·2 mm. $\frac{19\cdot6}{54}$"

At rate of tracing I $\frac{12\cdot6}{54}$" $\frac{8\cdot5}{54}$"

" " " " II $\frac{12\cdot9}{54}$"

Case II. 73·0 mm. $\frac{21\cdot6}{54}$" 1 min. 31·4 mm. $\frac{12\cdot6}{54}$" 1 min. 29·2 mm. $\frac{12\cdot6}{54}$" 1½ min. 22·4 mm. $\frac{11\cdot4}{54}$"

At rate of tracing I $\frac{9\cdot3}{54}$" $\frac{8\cdot7}{54}$" $\frac{6\cdot6}{54}$"

" " " " II $\frac{11\cdot7}{54}$" $\frac{9}{54}$"

" " " " III $\frac{9\cdot7}{54}$"

Case III. 71·75 mm. $\frac{35}{54}$" 3 min. 42·6 mm. $\frac{18\cdot6}{54}$" 2½ min. 26·4 mm. $\frac{20\cdot6}{54}$"

At rate of tracing I $\frac{20\cdot8}{54}$" $\frac{12\cdot8}{54}$"

Case IV. 44·4 mm. $\frac{13\cdot8}{54}$" 2¼ min. 32·6 mm. $\frac{13\cdot8}{54}$" 1 min. 17·2 mm. $\frac{10}{54}$"

At rate of tracing I $\frac{10\cdot1}{54}$" $\frac{5\cdot3}{54}$"

" " " " II $\frac{7\cdot3}{54}$"

Case V. No diminution of velocity.

Weight 2 kilos.

Case I. 53·8 mm. $\frac{28\cdot9}{54}$" 45 secs. 34·8 mm. $\frac{35\cdot6}{54}$" 1¾ min. 15·4 mm. $\frac{21\cdot4}{54}$"

At rate of tracing I. $\frac{19\cdot1}{54}$" $\frac{8\cdot2}{54}$"

" " " " II $\frac{15}{54}$"

Case II. No tracings.

Case III. 50 mm. $\frac{37}{54}$" 30 secs. 23 mm. $\frac{23}{54}$" 45 secs. 20 mm. $\frac{24.7}{54}$" 30 secs. 16 mm. $\frac{19.7}{54}$"

At rate of tracing I $\frac{17}{54}$" $\frac{14.8}{54}$" $\frac{11.8}{54}$"

" " " " II $\frac{20}{54}$" $\frac{16}{54}$"

" " " " III $\frac{19.7}{54}$"

Case IV. 49 mm. $\frac{25}{24}$" 30 secs. 30 mm. $\frac{17.3}{54}$" 1 min. 12.3 mm. $\frac{10}{54}$"

At rate of tracing I $\frac{15.3}{54}$" $\frac{6.3}{54}$"

" " " " II $\frac{7.1}{54}$"

Case V. 32.5 mm. $\frac{16}{54}$" 1 min. 20 secs. 14.25 mm. $\frac{8.75}{54}$"

At rate of tracing I $\frac{7}{54}$".

I shall not attempt to deduce conclusions from these figures; the cases on which they are based are too few. But I submit them as an indication of the work which the instrument employed seems likely to perform, that is, to serve as a ready means of estimating at once the diminution in the extent of a muscular contraction caused by fatigue, and the accompanying diminution in velocity. My original purpose of making upon these larger plates a series of pen-movements and finger-movements, rapidly following each other, was simply another means of estimating the effects of fatigue, and one in which a much larger series of plates must have been used. The instrument might be improved by the introduction of a further piece of mechanism, by which the recording part of it might be made to travel at a uniform and known rate away from the pointer. But every fresh complication of mechanism puts fresh difficulties in the way of observation, and it is doubtful if the advantage to be gained would compensate for this disadvantage.

In conclusion, I may mention a little recording instrument which I have devised, to register the involuntary movements of the tongue. Dr Mackendrick suggested to me that this might also prove an interesting investigation. The instrument consists of a small hemisphere of aluminium, into which a minute tube of the same metal opens. To this tube is attached a thin

rubber tube, carrying a small clamp, and ending in a hollow rubber ball. When the clamp is open, this ball is compressed by the hand, and the hemisphere of aluminium is then placed upon the tongue. The pressure is removed from the ball, and the air is thus exhausted from beneath the aluminium cup. The clamp is then closed, and the ball and rubber tube, which is in two pieces, withdrawn. The cup adheres to the tongue by atmospheric pressure. It carries a fine bristle, the extremity of which is made to rest on the smoked plate of the recording instrument I have described. The tongue is held as motionless as possible, and the plate is slowly run away from under the bristle. A line is thus left upon the plate, which indicates the extent of the movements of the tongue. I have no experience of this instrument beyond one plate (444), derived from myself. I was naturally unable to observe the time occupied by the tracings, from the position which I had to adopt. But they serve to show that in me at least the involuntary divagations of the organ have earned for it the right to be called an unruly member.