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# *Is the "Knee-Kick" a Reflex Act?*

A RESEARCH MADE AT THE PHYSIOLOGICAL LABORATORY OF THE COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK.

BY

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# IS THE "KNEE-KICK" A REFLEX ACT?

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BY WARREN P. LOMBARD, M.D.[1]



THE experiments here recorded were made in the Physiological Laboratory of the College of Physicians and Surgeons. I take this opportunity to express my thanks to Dr. John G. Curtis for his kind advice and assistance.

## CHARACTER AND RESULTS OF THE EXPERIMENTS.

The object of the research described in this paper was to determine whether the time between the moment of the blow on the ligamentum patellæ and the beginning of the following contraction of the quadriceps muscle, is long enough to permit the phenomenon to be a reflex act. The result was the discovery that this period was only about one-fourth as long as that required for a skin reflex from the knee, and very little longer than that seen when the quadriceps muscle is incited to action by direct electrical stimulation.

## CURRENT THEORIES.

Since 1875, when the attention of physicians was first called to the diagnostic importance of the phenomenon known as "knee phenomenon," "patella-tendon reflex," "knee-jerk," "knee-kick," "myotatic contraction," etc., there has been much thought given to the subject. The literature is already considerable. I have beside me over a hundred references, and there are undoubtedly many more. It would seem that there could be little new to say, but, in truth, all this work has not definitely determined the nature of the process, and it is not known today whether it is a reflex action or not.

There are two leading views concerning the matter; the one regards

[1] The author takes the occasion of the publication of the first research which he has made since leaving Leipzig, to express his affection and gratitude to his revered teacher, Prof. Carl Ludwig, and to utter the hope that the love of physiology which he inspired may some day bear fruit.

the contraction of the quadriceps muscle which follows a blow on the ligamentum patellæ as a reflex act, the other considers that it is due to mechanical stimulation of the muscle fibres. It has also been proved by experiments that the organ stimulated is, under normal conditions, not in the skin and not in the part of the tendon struck, but that it is situated at a distance, and is simulated by the sudden twitch and by the vibrations of the tendon, resulting from the blow. The nerve fibres which have been discovered in the tendon, near its attachment to the muscle, and in the sheath and the interstitial tissue of the muscle, as well as the muscle fibres themselves, are capable of being excited to action by mechanical stimuli, and they both seem to be in position to be affected by any sudden jerk or vibration of the tendon. Which of these organs is stimulated? If it be the afferent nerve fibres, the action is reflex; if it be the efferent nerve fibres or the muscle fibres, it is a local phenomenon. Both those who regard the knee-kick as a reflex act and those who consider it an entirely muscular operation admit that the integrity of the reflex arc is necessary to the phenomenon, for this has been proved by physiological experimentation as well as by clinical and pathological observations.

The chief argument in favor of the reflex idea is simply that the undoubted influence of the cord over the phenomenon can be satisfactorily explained in no other way. An explanation is given, however, by those who consider the process to be entirely muscular. They claim that the irritability of the muscle to mechanical stimuli is dependent on the tonus of the muscle, and that this condition is dependent on a continuous shower of weak reflex impulses from the cord. The loss of any part of the reflex arc is followed by a loss of muscle tonus, and, consequently, by a loss of the "knee-kick." The strength of this theory is somewhat impaired by the fact that we know little or nothing concerning muscle tonus, and that some observers state that it is not to be discovered by the most careful methods of experimentation.

The great argument advanced against the theory that the "knee-kick" is a reflex act, is based on experiments which are thought to show that the time elapsing between the moment of the blow on the ligament and the beginning of the contraction of the quadriceps muscle is too short for a reflex action. Thus the majority of observers find the interval to vary between 0.030 second and 0.040 second, except under abnormal conditions, when, in lateral sclerosis, for example, it has been found as short as 0.016 second. Such intervals of time are compared with the presumable reflex time, and are found to be three times as short as they should be were the action a reflex process.

The reflex time for such an act as the "knee-kick" is, unfortunately, unknown and has to be calculated. Thus, it is said that the whole reflex time is the sum of: 1. The time required for the transmission of the nerve impulse through the afferent and efferent nerves (a distance of 1½ metres at the rate of 30 metres a second), 0.045 second; 2. The time occupied by the reflex processes within the spinal cord (according to Exner's determinations from experiments on winking), 0.055 second; and, 3. The latent period of the muscle (determined on frog's muscle), 0.010 second. The whole reflex time is, therefore, said to equal about 0.110 second, while the interval between the blow and the contraction of the quadriceps equals only 0.030–0.040 second.

The champions of the reflex theory can scarcely doubt the accuracy of the experiments in which so many competent observers have gained the same results, but they answer that the time of such a reflex act as the "tendon reflex" may well be much more rapid than that which has been calculated. Thus, some observers have stated the rate of transmission of nerve force at 90 metres a second, instead of 30 metres, the assumed rate. The time Exner found for winking may not at all apply to processes in the lumbar cord. One has no right to judge the latent period of man's muscle from that of frog's muscle. In fact, there is no proof that the "tendon reflex" is not a very rapid reflex act.

And thus the question is left undecided, neither party being able to advance any absolutely conclusive argument.

## Experiments by the Author.

Study of the work already done on this subject led me to think that it was quite possible that the contraction of the quadriceps muscle following a blow on the ligamentum patellæ was a compound act; that both sensory nerve fibres and muscular fibres were stimulated by the twitch; and that the contraction was due, first, to direct mechanical stimulation of the muscle fibres, and, second, to reflex nerve impulses. This might well be the case, and yet the two movements might be so fused together that the unaided eye would be unable to distinguish them. The idea naturally suggested itself, that, by the graphic method, one might get a curve which would reveal the influence of two separate impulses. Moreover, one could measure the intervals of time elapsing between the moment that the blow was struck and the instant that each of the waves of contraction, resulting from the two impulses, should begin to show itself, and could compare these intervals with the period elapsing before the contraction of the muscle when it was stimulated directly by an induction current, or, reflexly, by an impulse coming from the skin near the knee. If when the ligamentum patellæ was struck, two oscillations of the curve of contraction should be seen, and two intervals should be obtained which corresponded, the one, with those got when the muscle was stimulated by electricity, and the other, with those got when the muscle was stimulated by reflex impulses, the cause of the contraction would be evident. If, on the other hand, no second interval should be seen, it would be no proof that the act was a simple one; but the time elapsing before the beginning of the contraction might be found to correspond to one or the other of these periods, and at least the true nature of the beginning of the phenomenon might thus be disclosed.

Accordingly, a number of experiments were made, in which the moment when the stimulus was applied and the moment when the quadriceps muscle had contracted sufficiently to move the foot were accurately recorded. The stimulus was applied in three different ways, viz.: 1. Directly to the muscle, by an induction current sent into it through the skin; 2. Indirectly, by a blow on the ligamentum patellæ; and, 3. Reflexly, by means of irritants employed on the skin near the knee. A study of the form of the curves and of the intervals of time thus obtained gave the following results.

Under normal conditions, when the ligamentum patellæ is struck, the curve of the resulting contraction of the quadriceps muscle shows an unbroken rise, followed by an equally regular fall, and presents no peculiarity which would suggest that the muscle had received more than one stimulation.

The shortest interval between the moment of stimulation and the beginning of the contraction, as registered by the movement of the foot, is seen when the muscle is stimulated directly by the induction current; the next shortest, when it is stimulated by a blow on the ligamentum patellæ; and the longest, when it is stimulated by a reflex impulse coming from the skin near the knee. The time determinations of these intervals were gained in each case by the same apparatus, and can, therefore, be safely compared.

The following table shows the percentage in which an interval of any given length occurred in the experiments of each day, and in the total number of experiments, made with each of the three methods of stimulation. Under Series I. are grouped all that series of experiments in which the rectus was stimulated directly by electricity; under Series II. are grouped those experiments in which the stimulus was a blow on the ligamentum patellæ; and under Series III. are grouped those experiments in which the muscle was stimulated by a reflex impulse from the skin near the knee. The experiments of different days are placed in separate columns, and the letter beneath the date represents the name of the man experimented on. At the left hand of the table, beneath the word seconds, is a column of the intervals seen to elapse between the moment the stimulant was applied and the moment the foot began to be moved by the contracting quadriceps muscle. On the same line with each interval is seen the percentage of the experiments of each day in which that interval occurred; and at the right hand of the table, under I., II., III., stand the percentages of all the experiments having this interval by each of the three methods.

At the bottom of the table are two lines of figures arranged by series and dates. The upper line gives the number of experiments made on each day by each method of irritation, and also the total number of experiments made with each method of irritation. The lower line gives the average length of the intervals obtained from these experiments.

A glance at this table shows a great similarity in the length of the intervals in the experiments of Series I. and Series II., whilst the intervals of the experiments of Series III. are all very much longer than these. A comparison of the lengths of the average intervals got from experiments in Series I. and II.—*i. e.*, from experiments in which the muscle was stimulated by the direct application of electricity, and those in which it was stimulated by a blow on the ligamentum patellæ—reveals a difference of only 0.007 second. This similarity suggests a similarity in the phenomena. Comparison of these average intervals with the average interval of experiments in Series III.—that is, those in which the muscle was stimulated by a reflex impulse from the skin—discloses the fact that the average interval for experiments in Series III. is three to four times as long as the average intervals of experiments in Series I. and II.

How far may these average intervals be trusted for purposes of comparison? In all experiments marked variations in the length of the intervals were seen. They were least when the muscle was stimulated by electricity, more when the stimulant was a blow on the ligamentum patellæ, and by far the greatest when the stimulus was of reflex origin.

When the muscle was excited to contraction by direct electric stimulation, the average length of the intervals obtained from the experiments of each day was between 0.060 second and 0.070 second; the length of the average interval got from all the experiments was 0.064 second; and 47.5 per cent. of all the experiments had intervals ranging between 0.060 second and 0.070 second. Outside of these limits the variations were as follows: 29.4 per cent. had shorter, and 23 per cent. had longer intervals. These figures make it evident that 0.064 second is a just average interval.

When the muscle was stimulated by a blow delivered on the ligamentum patellæ, the average length of the intervals obtained from the experiments of each day varied from 0.050–0.090 second; the length of the average interval got from all the experiments was 0.071 second; and 36.9 per cent. of all the experiments had intervals ranging from 0.060–0.080 second; 30.7 per cent. had shorter, and 32.4 per cent. had longer intervals. Thus, though one must remember that the intervals varied widely, one can fairly state the average interval at 0.071 second.

Similarly, it may be said that the average interval obtained from experiments in Series III. may fairly be accepted for purposes of comparison.

TABLE OF PERCENTAGES, ETC., JANUARY AND FEBRUARY, 1886.

| Seconds. | Series I. | | | | | Series II. | | | | | | | | Series III. | | | | | Total. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feb. 5. | Feb. 8. | Feb. 9. | Feb. 23. | Feb. 25. | Jan. 21. | Jan. 26. | Feb. 5. | Feb. 6. | Feb. 8. | Feb. 9. | Feb. 23. | Feb. 25. | Jan. 26. | Feb. 8. | Feb. 9. | Feb. 23 | Feb. 25. | I. | II. | III. |
| | A. | B. | C. | D. | D. | A. | B. | A. | D. | B | C. | D. | D. | B. | B | C. | D. | D. | A, B, C, and D. | A, B, C, and D. | B, C, and D. |
| 0.03–0.04 . . . | ... | ... | 9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 7 | ... | ... | ... | ... | ... | 1.6 | 0.9 | |
| 0.04–0.05 . . . | ... | 6 | ... | ... | ... | 29 | 9 | ... | ... | 11 | 9 | ... | 43 | ... | ... | ... | ... | ... | 1 6 | 12.3 | |
| 0.05–0.06 . . . | 20 | 40 | 27 | 30 | 13 | 71 | 9 | 60 | ... | ... | 4 | ... | 36 | ... | ... | ... | ... | ... | 26.2 | 17.5 | |
| 0.06–0.07 . . . | 40 | 20 | 46 | 50 | 80 | ... | 9 | 20 | ... | 11 | 18 | 7 | 7 | ... | ... | ... | ... | ... | 47.5 | 8.8 | |
| 0.07–0 08 . . . | 30 | 20 | 9 | 20 | 7 | ... | 55 | 20 | 63 | 33 | 23 | 39 | ... | ... | ... | ... | ... | ... | 16.5 | 28.1 | |
| 0.08–0.09 . . . | 10 | 7 | 9 | ... | ... | ... | 9 | ... | 37 | 23 | 27 | 35 | 7 | ... | ... | ... | ... | ... | 4.9 | 20 9 | |
| 0.09–0.10 . . . | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 5 | 16 | ... | ... | ... | ... | ... | ... | ...... | 5.3 | |
| 0.10–0.15 . . . | ... | 7 | ... | ... | ... | ... | 9 | ... | ... | 11 | 14 | 3 | ... | ... | 8 | .. | ... | ... | 1.6 | 5.3 | 2.1 |
| 0 15–0.20 . . . | ... | ... | ... | ... | ... | ... | ... | ... | ... | 11 | ... | ... | ... | 16 | 25 | ... | ... | 8 | ...... | 0.9 | 10.4 |
| 0 20–0.25 . . . | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 17 | 42 | 34 | 34 | 75 | ...... | ...... | 43.7 |
| 0.25–0.30 . . . | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 17 | ... | 33 | 33 | 17 | ...... | ...... | 18.7 |
| 0.30–0.35 . . . | ... | ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | 50 | 17 | 33 | 33 | ... | ...... | ...... | 22 9 |
| 0.35 . . . | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 8 | ... | ... | ... | ...... | ...... | 2.1 |
| No. of experiments . | 10 | 15 | 11 | 10 | 15 | 14 | 11 | 5 | 8 | 9 | 22 | 31 | 14 | 6 | 12 | 9 | 9 | 12 | 61 | 114 | 48 |
| Average interval . . | 0 068 | 0.067 | 0.061 | 0.063 | 0.063 | 0.052 | 0.075 | 0 060 | 0.079 | 0.090 | 0.077 | 0.082 | 0.051 | 0.271 | 0.232 | 0.268 | 0.270 | 0.226 | 0.064 | 0.071 | 0.253 |

Before any conclusion as to the similarity or dissimilarity of these phenomena can be based on a comparison of their average intervals, one must ascertain upon what the differences in the average intervals depend. An analysis of the interval recorded as elapsing between the moment that the stimulus was applied and the moment the foot began to move in response to the contraction of the quadriceps muscle, shows that it is made up of the following periods, viz.:

1. The time occupied by all the processes occurring between the moment the stimulant is applied and the moment the stimulus reaches the muscle. This period would vary with each form of stimulant, and would depend on the length and the nature of the path which the stimulus had to travel.

2. The time required for the muscle to respond to the stimulus. The latest observations state the latent period of the normal frog's muscle at about 0.003 second. We do not know the latent period of man's muscle. It would, without doubt, vary with the irritability of the muscle. As in these experiments the subjects were normal and were placed under the same conditions, the latent period of the muscle can be regarded the same in all the experiments.

3. The time required for the muscle to contract enough to move the foot. This would depend on—

*a.* The tension of the muscle at the time it was irritated. This was very slight and was apparently the same in all the experiments.

*b.* The amount the contracting muscle was stretched by the resistance of the leg, etc. This was the same in all experiments.

*c.* The time required for the contracting muscle to overcome the inertia of the limb and of the recording apparatus. This would be, probably, about the same as the time required to register the jar of the blow. This period was determined by fifty experiments to be about 0.013 second. It was about the same in all experiments.

*d.* The number of muscle fibres irritated, which would vary with the nature of the stimulant, its strength, and the method of its application.

*e.* The strength of the stimulus.

4. All the intervals recorded are 0.003 second too short, for this amount of time was lost by the electro-magnet in recording the moment of the blow.

The periods numbered 2, 4, and *a*, *b*, and *c*, under 3, were the same for all forms of experiments and need not be further considered. Any differences seen between the average intervals obtained by the three different methods of experimentation were dependent on differences in the length and nature of the paths which the stimulus had to travel; on differences in the number of muscle fibres stimulated, due to differences in the nature, strength, and method of application of the stimulant; and on differences in the strength of the stimulus.

How far would those causes which determine the activity of the contraction of the muscle affect the result? In the case of experiments in which the muscle was stimulated by electricity, the electrodes were only six inches apart, and, therefore, comparatively few muscle fibres were directly stimulated; the stimulus may have spread to many others, however, by means of the nerves which were excited. The stimulant employed was of medium strength, an induction current being chosen which just sufficed to cause an undoubted movement of the foot. These facts would lead one to surmise that a comparatively long time elapsed between the moment that the stimulus reached the muscle and the moment the foot began to move in response to its contraction.

In the case of experiments in which the muscle was stimulated by the results of a blow on the ligamentum patellæ, if the stimulation was reflex, all the muscle fibres must have been stimulated in each experiment; if the stimulation was effected by direct excitation of the muscle fibres, the number of fibres stimulated must have varied with the tension of the muscle, the force of the blow, and the place struck. The strength of the stimulus, though undoubtedly very variable, was, to judge from the extent of the movement of the foot, in most experiments, considerable. These facts lead one to believe that a comparatively short time elapsed between the moment that the stimulus reached the muscle and the moment the foot began to move in response to its contraction.

There is no way of accurately determining how many muscle fibres were stimulated by either method of experimentation, or what was the relative strength of the stimulants employed. The above facts, however, would lead one to infer that the contraction of the muscle would have been comparatively slow in experiments in which the muscle was stimulated by electricity, and, so far as this influence could have determined the result, that the average interval would have been somewhat longer in these experiments than in those in which the muscle was stimulated by the results of a blow on the ligamentum patellæ. In reality, however, the reverse was true, and the average interval of experiments in Series I. was 0.007 second shorter than that of experiments in Series II. This result can be due only to the other factor which goes to determine the length of the intervals—that is, the length and nature of the paths which the stimulus had to travel in the two cases. The stimulus has, then, to pass by a longer path in the case of experiments in which the ligamentum patellæ is struck than in the case of those in which the quadriceps is stimulated by electricity; and this difference in the length and nature of the paths is enough to make the average interval of the experiments of Series II. not only as long, but 0.007 second longer than that of the experiments of Series I. As has been said, there is no way of determining what effect the possible difference in the number of muscle fibres stimulated by the two methods of experimentation, and the possible difference in the strength of the stimulant employed in the two cases, may have had on the average intervals; one can only conclude that the difference in the length and nature of the paths travelled in the two cases is somewhat more than is represented by 0.007 second.

What are the paths which the stimulus would have to pass over when the two methods of stimulation under consideration are employed? In the case of electric stimulation the electricity would only have to pass from the wet electrode, through the moist skin, the subcutaneous tissue, and the fascia to reach the muscle. In the case of a blow on the ligamentum patellæ, if the muscle fibres were stimulated mechanically, the jerk and the vibrations of the ligament would have to be transmitted along the chain of ligament, patella, quadriceps tendon, and quadriceps muscle. If the muscle were stimulated reflexly, the stimulus would have to pass, in addition to the above, through the afferent nerves to the spinal cord, through the reflex mechanisms in the cord, and through the efferent nerves to the muscle. There can be little doubt by which path the stimulus would soonest reach the muscle. The muscle would be stimulated soonest by electricity, almost as soon by the mechanical stimulation of a sudden jerk transmitted to it from the tendon, and some time later by reflex stimulation.

The difference between the periods of time required for the stimulus to pass from the point to which the stimulant was applied, to the muscle, in the experiments of Series I. and II., is, as has been stated, somewhat more than 0.007 second. Were the stimulation reflex in character, we should expect a very marked difference. The reflex time for such a process as the "knee-kick" has been supposed to be, cannot be calculated, because the rapidity of different reflex processes probably varies greatly; we may, however, obtain a rough idea of its length. It is the sum of the following periods, viz.:

1. The time required for the transmission of jerk and vibration, resulting from the blow, from the ligament to the sensory nerve ends in the tendon or muscle, and the time spent by them in awakening to activity. This period cannot be determined.

2. The time required for the transmission of the stimulus through the afferent nerves to the cord, and from the cord through the efferent nerves to the muscles. At the quickest estimated rate of transmission of nerve force, 90 metres a second, 0.016 second would be required for the passage of the impulse through a metre and a half of nerve length. Exner, in his calculations, uses the rate of 62 metres a second; at this rate 0.024 second would be required. By the more usual estimate, of 30 metres a second, nearly 0.050 second would be required for the transmission of the impulse to and from the cord.

3. The time occupied by reflex processes within the cord is probably

very variable. Exner found it, in his determinations on winking, to equal 0.055 second.

4. The latent period of the muscle.

It is not worth while to add these periods together, for the result would give no accurate idea of the reflex time. The only use of referring to them is to show that, so far as we can judge from present knowledge, even rapid reflex processes require considerable time. Here it is interesting to compare the average intervals got by the experiments of Series I. and II. with the average interval of experiments of Series III., in which the stimulus was a reflex impulse called out by a vigorous electric irritation of the skin near the knee. The average interval of the experiments in Series I. is 0.064 second, that of the experiments in Series II. is 0.071 second, and that of the experiments in Series III. is 0.253 second—*i. e.*, the average interval of the experiments in which the muscle was stimulated by a reflex impulse from the skin near the knee is three or four times as long as that of the experiments in which the muscle was stimulated by electricity, or by a blow on the ligamentum patellæ. The fact that a portion of the reflex interval was occupied by a summation of the impulses produced by the induction shocks, makes little difference, for, as the current was quite strong, and the hammer of the induction apparatus was vibrating very rapidly, the summation would have occupied but little time.

It may well be said that a reflex process, such as the "tendon reflex" is supposed to be, might be very much shorter than that of a skin reflex from the knee. This is true, but that it might be so much shorter as to require but little more time than the direct electric stimulation of the quadriceps is not at all evident. On the other hand, the difference found between the average intervals of experiments in Series I. and II. is about what one would expect to find were the muscular fibres of the quadriceps stimulated mechanically by the jerk and vibrations which would result from the blow on the ligamentum patellæ.

There is one more point to which it is necessary to refer. Not only do the experiments in Series II. have intervals closely resembling those of the experiments in Series I., but a larger percentage of the experiments of Series II. have very short intervals than of the experiments in Series I. Thus, 12.3 per cent. of the experiments in Series II. had intervals ranging from 0.040–0.050 second, while only 3.2 per cent. of the experiments of Series I. had intervals as short. These very short intervals of Series II. are hard to reconcile with the idea that the stimulus had to pass through the cord before it reached the quadriceps muscle, but they might well have occurred had a vigorous blow on the ligament thrown all the muscle fibres into vibration.

The results of my experiments do not settle the question in dispute, but they add weight to the opinion already expressed by many competent observers, that the "knee-kick" is not a reflex act. Moreover, the mechanical conditions on which the "knee phenomenon" depends, the fact that muscle fibres are stimulated if they are suddenly twitched, and that the fibres of the quadriceps are in a position to be thus stimulated, and the time found to elapse between the blow on the ligamentum patellæ and the contraction of the quadriceps, all go to suggest that the phenomenon is entirely peripheral.

Although, as a rule, the contraction of the quadriceps which follows a blow on the ligamentum patellæ is a simple act, there was one set of experiments, among those recorded, which seemed to be an exception. Many of the curves got from one man, and on one day, showed an irregularity such as one might expect, if, when the original contraction of the muscle had reached its highest point, or when the muscle had even begun to relax, a second impulse had reached it, and caused it to contract still further. What was most interesting in this change in the form of the curve was that it occurred at an interval after the blow which closely corresponded to the interval got when the muscle was stimulated by a reflex stimulus coming from the skin near the knee. It suggested, of course, that the muscle received two impulses, as a result of the blow on the ligamentum patellæ, the one, a direct mechanical stimulation, the other, a reflex stimulus. The curve was never carried by the second oscillation to any marked height, however, and the chief part, as well as the first part of the "knee-kick," under normal conditions, at least, would seem not to be due to reflex stimulation. The rest of the curves obtained from the same man, on other days, and from the other men experimented upon, were searched in vain for any wave which might suggest the action of two separate impulses. The fact that such an oscillation of the curve was noticed is the more interesting because I have heard that de Watteville claims that the "knee-kick" is always a compound act.

As the results here given are of importance, and are liable to be questioned, it seems desirable that a more detailed account of the experiments and of the methods pursued should be given. I therefore state them here for those readers who are more especially interested in this subject.

## Requirements of the Research.

The experiments must be made on man.

The subject must be placed at rest, in an absolutely comfortable position, in order that there shall be no disturbing movements or unwished-for reinforcements.[1]

The thigh must be steadied by a form of support, which, while it prevents movement being caused by the jar of the blow, when the liga-

[1] Mitchell, The Medical News, February 13 and 20, 1886.

mentum patellæ is struck, does not press on the quadriceps muscle, or on the large vessels or nerves.

The leg must be entirely free to move in response to the contraction of the quadriceps, and the weight of the leg and foot must be as far as possible gotten rid of, in order that the muscle may not be stretched, and the beginning of the contraction be lost. The contraction, rather than the swelling of the muscle, must be recorded, because it is the more marked event, and more likely to reveal the character of the action.

The recording apparatus must consist of a rapidly moving surface, and of three writing points: one attached to a tuning-fork to record the rate at which the surface is moving; another, connected with an electro-magnet, to mark the moment the irritation is given; and a third, to write the contraction of the muscle.

In accordance with these requirements, the following apparatus was put together.

## Description of the Apparatus Used in the Experiments.

The man experimented upon lay on his left side on a comfortable couch, so formed as to support the head and back. The right thigh rested on a prop of plaster, shaped so as to conform to the inner and posterior surface of the thigh, and of such a height as to hold the knee on a level with the hip-joint. The right foot was supported by a swing suspended by a cord from the ceiling.

The movement of the foot, in response to the contraction of the quadriceps, was recorded as follows: A strong inelastic thread, attached by one end to the swing on which the foot was fastened, was guided by two accurately working pulleys to the top of the recording needle. One of these pulleys was on a movable stand, having a heavy base, and its position could be changed to correspond to the position of the foot, and thus the direction and the tension of the thread could be regulated. The other pulley held a fixed position, and the thread passing over it suspended the writing mechanism. This mechanism was cross-shaped, and consisted of a vertical shaft bearing a horizontal needle, which was adjustable at any desired height on the shaft. The vertical shaft was suspended from the end of the thread beneath the second pulley, and was insured free vertical movement and freedom from lateral oscillations by passing through two smoothly bored holes in two thin strips of metal, which were supported about fifteen centimetres apart by an iron standard. One end of the horizontal needle terminated in a fine rounded point, and rested against the blackened drum of a Ludwig kymographion (Baltzer's manufacture). Constant contact with the drum was secured by a fine plumb line, which hung against the other end of the needle. Contraction of the quadriceps and extension of the knee caused the needle to rise, while relaxation of the muscle and flexion of the knee were recorded by a fall of the curve. It was desired to detect any irregularity in the contraction of the quadriceps, and, therefore, it was especially necessary to prevent the needle from being thrown by the sudden jerk of the kick beyond the height which corresponded to the absolute movement of the foot. A thin yielding band of rubber was therefore attached to the lower end of the vertical shaft and to the floor.

The kymographion ran with great regularity, but this was not relied upon, and the rate of rotation was measured during each experiment by a tuning-fork, which, by means of a light metal point attached to one of the arms, wrote its vibrations on the drum.

An electro-magnet recorded, by a light lever attached to its armature, the moment the blow was struck on the ligamentum patellæ, or the moment that the induction current was thrown into the quadriceps muscle or the skin. The pattern of the magnet resembles that of Pfeil, of Berlin (described by Tigerstedt, *Arch. für Phys.*, Supplement Band, 1885), and its latent period was a little less than 0.003 second.

The instruments used for irritating were as follows:

The blow on the ligamentum patellæ was given by a medium-sized steel hammer, one end of the head of which was tapered to a dull edge, about an inch long and covered with a rounded rubber cap, of the thickness of a lead pencil. In cases in which the "knee-kick" was well marked, the ordinary percussion hammer was sufficient. The electric circuit of the recording electro-magnet was closed when a strip of platinum foil on the rubber end of the hammer touched a piece of gold braid, which was fastened by a garter over the ligamentum patellæ.

The induction current was applied to the rectus muscle by two wet electrodes, placed on the skin over the middle third of the muscle and about six inches apart. When it was necessary to stimulate the cutaneous nerves, the induction current was applied by a wire brush and a platinum point about half an inch apart.

In the case of electrical stimulation, one key simultaneously closed two circuits; the one going through the muscle, or the skin, the other through the electro-magnet.

A Grove cell was used for the electro-magnet, and another for the Du Bois-Reymond induction coil.

The same magnet recorded the moment of stimulation, and the same apparatus wrote the beginning of the contraction of the quadriceps, whatever the means of stimulation employed—*i. e.*, whether the muscle was stimulated by a blow on the ligamentum patellæ, by the direct application of the induction current, or by the reflex impulse resulting from the irritation of the skin near the knee. Therefore, the latent period for the apparatus was the same in all the experiments, and any difference in time which was found, was due to variations occurring between the moment the stimulant was applied and the moment the stimulated muscle had contracted enough to move the foot; in other words, to differences in the length and nature of the paths which the stimulus had to travel, and in the activity of the muscular contraction.

To conclude—from the experiments recorded in this paper, it would seem that the contraction of the quadriceps muscle following a blow on the ligamentum patellæ comes much too soon to be the result of a reflex stimulation. It is probable that the stimulation is due to a sudden stretching of the muscle fibres, and that the stimulus has the same character as when the muscle receives a direct blow. Before this conclusion can be accepted, however, the undoubted influence of the spinal cord upon the production of the phenomena must be explained. The current explanation that the irritability of the muscle to finer mechanical stimuli is dependent on "muscle tonus," will not be altogether satisfactory until the existence of "muscle tonus" is proved.

It seems probable, that, in addition to the first impulse which comes to the quadriceps when the ligamentum patellæ is struck, occasionally a second impulse, of reflex nature, originating either in the nerve ends of the skin or of the tendon and muscle, may come to it and increase the height of the contraction. Under normal conditions, however, this would seem to play a very subordinate part.