A STUDY OF THE KNEE JERK

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BY

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A THESIS

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CONTENTS

I.

The knee jerk is immediately caused by the sudden and vigorous contraction of the quadriceps muscle of the thigh. The quadriceps is the great extensor muscle of the leg, forming a large fleshy mass, which covers the front and sides of the femur. Sherrington[1] has demonstrated by experimentation upon animals that two of its four divisions, the *vastus internus*, covering the inner surface of the femur, and the *crureus*, covering the front of the femur, are chiefly involved in the knee jerk mechanism. These two portions are so intimately blended anatomically as to form a single muscle. So considered it is related by its superficial surface with the psoas and iliacus, the rectus, satorius, pectineus, adductors, and fascia lata; by its deep surface with the femur, sub-crureus, and synovial membrane of the knee joint.

The tendons of the different portions of the quadriceps unite at the lower portion of the thigh, so as to form a single strong tendon which invests the patella throughout its whole surface except underneath where a free articular surface is presented, and continues downward to be inserted in the rough bony prominence of the tibia. From the lower border of the patella to the insertion in the tuberosity of the tibia it is known as the ligamentum patellæ. The patella may therefore be properly regarded as a sesamoid bone, developed in the tendon of the quadriceps and the ligamentum patellæ. Immediately below the lower edge of the patella—one-half inch to an inch—the tendon passes over a slightly hollowed space in the parts beneath.

The nervous structures involved in the knee jerk mechanism have also been determined with exactness. Sherrington[1] has located the position of both the afferent and efferent conduction paths. He found the afferent path to lie in the posterior root of the fifth lumbar of the Rhesus monkey, which corresponds to the fourth of man. This posterior root receives afferent fibers from the obturator and anterior crural nerves, and from the external and internal popliteal nerves. By the method of severance and other modes of destruction of the conductivity of the nerves

[1] *Journal of Physiology*, Vol. 13, p. 666.

entering the root, *e.* g., cooling to the freezing point, etc., Sherrington found that of the fibers entering the root from these sources, those on which the jerk depends are not from any except the anterior crural nerve, and in the anterior crural nerve only those fibers which issue from the vastus internus and crureus muscles.

The peripheral terminations of the sensory conduction path are therefore found in the muscles whose contraction causes the movement. Further it is probable that some of these fibers also terminate in the tendon of the muscle.[1]

By the same method the efferent conduction path was found in the anterior roots of the fifth and fourth lumbar nerves of the Rhesus (fourth and third of man) and was traceable along the anterior crural nerve into those of the muscular branches of that trunk which supply the vastus internus and crureus divisions of the quadriceps, *i. e.*, in exactly the same muscles in which the afferent condition path has its peripheral termination.

Pathological evidence, offered by cases presenting degeneration of posterior nerve roots and certain portions of the posterior columns of the cord in which the knee jerk is observed to be entirely absent, makes it clear that the spinal center involved in the knee jerk mechanism is situated somewhere between the second and fifth lumbar segments inclusively. Mills[2] agrees with Edinger, Starr and others in placing it in the second or third lumbar segments or probably both.

A blow on the patella tendon (*a*) stimulates the peripheral sensory fibers terminating freely in the superficial tissue, (*b*) stimulates the peripheral sensory nerve fibers terminating in the tendon, (*c*) depresses the tendon thereby drawing it taut and exerting through its attachments a longitudinal stress upon the fibers of the quadriceps, thus offering a stimulus to the peripheral sensory nerve fibers terminating in the muscle itself, (*d*) by

[1] As to the manner in which sensory nerve fibers terminate in the tendons, Philipp Stöhr, in *Lehrbuch der Histologie*, 1901, says: "Die Sehnenspindeln sind meist spindelförmige Auftreibungen von Sehnenbündeln, die von einer gut entwickelten bindegewebigen Hülle umgeben werden. Das eine Ende der Spindel geht in Sehnenbündel über, das andere setzt sich in Muskelfasern fort. Die an die Mitte herantretenden Nervenfasern theilen sich wiederholt, verlieren ihr Mark und gehen in ein reich entwickeltes Astwerk über mit oft keulenförmig angeschwollenen Enden.

[2] *Journal of Nervous and Mental Disease*, 1899, p. 142.

depressing the tendon serves as a mechanical stimulus to the quadriceps.

With the given anatomical structures comprising the knee jerk mechanism and the given results of a blow on the ligamentum patellæ, three explanations of the physiological cause of the knee jerk are possible.

1. The knee jerk is a reflex. Stimulation of the sensory fibers terminating in the superficial tissue by contact or by an electrical current does not produce the movement, consequently if the jerk is a reflex, the peripheral excitation has its origin in the tendon or muscle (or both). In either case the course of the afferent impulse is the same. "From the tendon of the patella, the excitation is carried to the spinal cord by crural sensory fibers, and enters by the dorsal root into a certain portion of the dorsal column, and thence passes to the dorsal horn; next it takes its course through the intermediate gray matter until it reaches cells of the ventral horn; and thence the motor excitation goes through the motor roots and crural nerve to the anterior muscles of the thigh."[1] Waller[2] objects to this theory on the ground that the time elapsing between the blow and the response is too short for the transmission of an excitation over a reflex arc. By exact measurement he found the time between the percussion of the tendon and the contraction to be between .03 and .04 second and between the direct percussion of the muscle and the contraction .03 second. Exner's reflex, the winking of the eyelid, has a latent time of .05 seconds. Aside from this one instance a knowledge of normal reflex times is still wanting.

2. The knee jerk is a muscular contraction due to the direct mechanical stimulation of the muscle. On this theory the function of the nervous structures involved, *i. e.*, an afferent and efferent conduction path and a spinal segment, any interruption of which results in a total loss of the jerk, is to maintain by means of a constant reflex influence, the tonicity of the muscle. With the tone present the muscle reacts directly to the mechanical stimulus. Opposed to this theory is the fact that the knee jerk may be present when muscle tone appears to be wanting and may be absent in the case of men who apparently have a normal

[1] Mills, *Journal of Nervous and Mental Disease*, 1899, p. 142.
[2] *Journal of Physiology*, Vol. 11, p. 384.

amount of tone.[1] Further the theory does not satisfactorily explain the facts of reinforcement, *e. g.*, the increase in the extent of the kick when the hands are clinched just before the tendon is struck. Lombard[2] made a study to determine the changes in the tone and irritability of the quadriceps and found that neither increased under reinforcing conditions.

3. The knee jerk is first due to the mechanical stimulation of the muscle and second to the reflex excitation, *i. e.*, the muscle contracting in response to the mechanical stimulus represents the beginning of the kick, while the reinforcement or continuance of the movement is the result of the reflex impulse. Lombard[3] reports the results of one case which showed an irregularity "which 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." Although this result lends support to the theory, the non-observance of this irregularity in all knee jerk records is not evidence to the contrary. The reflex influence may gradually become operative quite before the movement due to the mechanical stimulation had reached its maximum height, in which case the irregularity would not appear in the record. Improved methods of recording the excursion of the leg may reveal different rates of movement during different divisions of the excursion and thereby furnish more conclusive evidence on this point. Some evidence for this theory is presented in Part III of this study.

The following study comprises (1) an attempt to determine as nearly as possible the extent of the unaugmented or normal knee jerk for normal subjects and (2) a consideration of the modifications it is observed to undergo during an extended period of experimentation. When the patella tendons are struck at exactly the same place with blows of constant force and at regular intervals, no two of the resulting knee jerks are of the same extent. This variation is usually referred to some accidental stimulus acting upon the subject, *e. g.*, a loud or distracting sound or to an idea to which the subject directs his attention, an emotional state of greater or less intensity, any one of which conditions may

[1] See Diagram, p. 17.

[2] *Journal of Physiology*, Vol. 10, p. 122.

[3] *American Journal of Medical Science*, Vol. 93, p. 88.

produce a variation in the extent of the jerk, or in a general way to a change in the activity of the central nervous system.[1] From the very nature of the case such sources of variation are not wholly avoidable. However secure the subject may be kept from accidental sensory stimuli, the stream of consciousness is never altogether within control of the experimenter and the organic processes of digestion, circulation, etc., are constantly producing some slight or more profound modification in the equilibrium of the nervous system.

The results of a study made by Noyes[2] on the unaugmented knee jerk in sleep in a case of terminal dementia suggest a more definite explanation for the variations occurring in kicks following in close succession when the conditions remain precisely the same. Noyes obtained the knee jerk curve and the Traube-Hering curve for the same period and found a well-marked coincidence between them. A comparison shows that the Traube-Hering curve descends lowest in that part of the group of knee jerks where the kicks are longest and at the place where the Traube-Hering curve is highest the knee jerks are much diminished. A rise in the Traube-Hering curve indicates increased blood pressure in the arm, and a fall in the curve corresponds to diminished blood pressure.

On the theory that increased blood pressure in the extremities means lessened blood pressure in the central nervous system there is relative anaemia of the brain and cord when the Traube-Hering curve is at its height, and relative hyperaemia of the brain and cord when the curve is lowest. The diminished knee jerk would then follow from the lessened functional activity of the spinal cord at the height of the Traube-Hering wave, while an increased knee jerk from increased functional activity of the cord would follow at the low phase of the peripheral Traube-Hering curve.

Although these results were obtained from a demented subject there is no reason for believing that the same relation would not

[1] In a consideration of these variations Sommer says: "Es müssen demnach in den betreffenden Individuen Kräfte wirksam sein, welche den Reflex hemmen oder verstärken. Diese Curvenreihen sind der einfachste Ausdruck eines variablen Momentes im Nervensystem, vermöge dessen bei gleichem Reiz verschiedene Wirkungen zustande kommen."—*Psychopatholog. Untersuchungs-Methoden*, 1899, p. 30.

[2] *American Journal of Psychology*, Vol. IV, No. 3.