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The rôle of the dorsal roots in muscle tonus.

S. W. RANSON. (Introduced by Leo Loeb).

[*From the Department of Neuro-anatomy, Washington University Medical School, St. Louis, Mo.*]

It is hard to see why cutting the sensory fibers for a muscle should abolish its tonus since powerful tonic contraction can be induced from the vestibular labyrinth, from the sensory nerves of the opposite limb and from other sources. It would seem as if afferent impulses from these sources should be able to maintain at least a moderate degree of tonus in the absence of those coming from the muscle itself.

For this reason Frank[1] has suggested that the dorsal roots are important in this connection not so much because they carry sensory fibers from the muscles as because they contain efferent fibers through which tonic impulses are conveyed to the muscles. Such special tonic fibers might be thought of as causing a jellying or increase in viscosity of the contracted muscle thus delaying its relaxation. Frank failed to subject his hypothesis to a thorough experimental test and partly for this reason, and partly because it is in conflict with Bell's law, his theory has received but scant consideration.

The results of our experiments can be made to agree with neither of these theories regarding the origin of tonus. If the long dorsal roots of the sacral and lower lumbar nerves are cut close to the spinal cord and at a distance of from 1 to 1½ inches from the spinal ganglia, the muscles of the corresponding hind limb become atonic for only about 24 hours. After this tonus gradually returns, the extensor muscles usually become markedly tonic and the limb is held in a hyperextended position. There develops considerable resistance to passive flexion. This stiffness usually reaches its maximum about one week after the operation and then gradually subsides during the next two weeks.

Magnus[2] cut extradurally the dorsal roots containing the sensory fibers for the left triceps. The extradural part of the dor-

[1] Frank, E., *Arch. Exp. Path. u. Pharm.*, 1921, xc, 149.

[2] Liljestrand, G., and Magnus, R., *Arch. f. d. ges. Physiol.*, 1919, clxxvi, 168.

sal root is so short that he must have cut within a millimeter or two of the ganglion or possibly through the proximal part of the ganglion. Ten days after the operation he injected equal quantities of tetanus toxin into both triceps. When a small amount of this toxin is injected into an animal the response is sharply localized and takes the form of a continuous tonic shortening of one or more muscles, usually of all the muscles of a single extremity. In Magnus' experiment this tonic shortening developed in the usual manner in the right triceps three days after the injection; but the tetanus toxin had no effect whatever on the deafferented left triceps. He concluded that the muscular rigidity of tetanus is produced reflexly by afferent impulses coming from the affected muscles and passing through spinal cord whose reflex excitability has been increased by the action of the toxin.

We have found, however, that if instead of making the section close to or through the proximal end of the ganglion, the long dorsal roots of the sacral and lower lumbar nerves are cut close to the cord, *i. e.*, at a distance of from 1 to 1½ inches from the ganglia, tetanus develops even earlier in the deafferented than in the normal limb. These experiments show that if one is careful to avoid damaging the spinal ganglia section of the dorsal roots, instead of preventing the development of local tetanus, favors it, so that the muscles of the deafferented limb become rigid even more quickly than do those of the normal side. This demonstrates that the afferent impulses from the affected limb play no essential part in the development of the tonic contraction of tetanus.

Extradural dorsal root section, as practiced by Magnus, probably damages the spinal ganglia and we believe that this damage to the ganglia accounts for the fact that his cats did not develop tetanus in the deafferented muscle. All of our results point toward these ganglia on the dorsal root as playing a very important role in the tonic innervation of the muscles. We have shown, for example, that the local application of nicotine or chloral hydrate to the spinal ganglia interrupts the passage of tonic impulses responsible for decerebrate rigidity. This indicates that these impulses pass through synapses in the ganglia.

Much more work must be done before one would be justified in formulating a general statement as to the part played by the dorsal roots and spinal ganglia in muscle tonus. The diagram illustrates the working hypothesis which we are using as a guide in

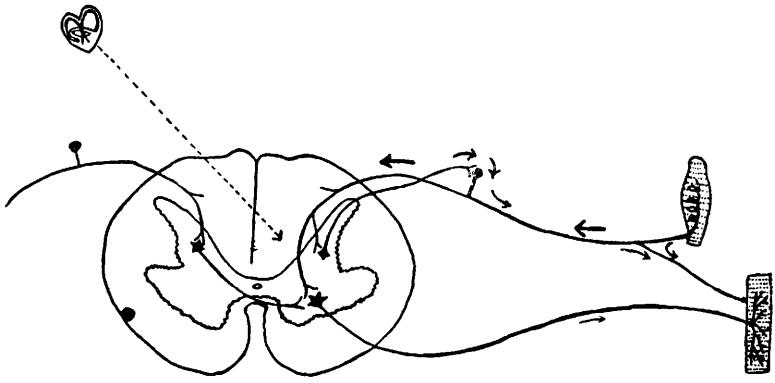

Diagram of possible reflex arcs concerned in muscle tonus.

planning future experiments. It assumes that tonic impulses coming from the spinal cord along the dorsal roots pass through synapses in the spinal banglia and are relayed along the sensory fibers to the muscles. These are assumed to give off side branches with special endings on the muscle fibers. As a necessary corollary we must assume the possibility of axon-reflex-tonus. This would bring the tonic innervation of the muscles into the same category as the vasodilator innervation of the blood vessels.

It is possible that tetanus toxin may act by increasing the excitability of this axon-reflex-arc and this possibility we expect to test by removing the spinal ganglia and allowing the sensory fibers to degenerate before injecting the toxin.

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A test for bile salts in urine.

G. O. BROUN. (Introduced by R. Kinsella).

[*From St. Louis University School of Medicine, St. Louis, Mo.*]

A search through the text books of physiological chemistry reveals two tests that are used for the detection of bile salts in urine. One is the Pettenkofer reaction which depends on the production of a red coloration when a strong acid, furfural, and