237 (2197)

Reflex contractions of an all-or-none character.

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Sherrington's emphasis on the differences between reflex arc conduction and conduction in the nerve trunk has long been familiar to physiologists. With the establishment of the all-or-none law for muscle and for nerve in recent years it was but natural that the query should be raised as to whether reflex action be bound by the limitations of the all-or-none behavior of muscle and of nerve, or whether the central nervous system so alters the final nerve impulse to muscle that it can over-ride these limitations. A single sensory impulse, for example, might always result in a volley of impulses along the final motor neurones, according to Sherrington's suggestion.[1] Variations in the number of impulses comprising this volley might, by summation of contractions, conceivably produce in the muscle degrees of response of almost any grade of fineness, and reflex contractions would not then show an all-or-none character.

The present research was undertaken with the object of comparing minimal, or close to minimal, responses of muscle secured by single shocks to its motor nerve, with similar responses obtained reflexly by stimulation of a sensory nerve.

The muscle employed was the tenuissimus, a long slender, straight-fibered muscle underlying the biceps and containing approximately one thousand fibers.[2] The nerve to this muscle contains about twenty motor neurones, each neurone presumably innervating approximately fifty muscle fibers. If this nerve be stimulated by single shocks gradually increasing in strength the response of the muscle is not gradual, but by step-like increments, there being no gradation between one step and the next. The heights of the first three increments to appear in three of such experiments are shown in Experiments I, II and III of the appended table. The response is of the same character as that observed by Lucas[3] in the dorso-cutaneous nerve muscle preparation in the frog. When the appropriate sensory nerve is sim-

1 Sherrington, *Proc. Roy. Soc.*, 1921, xcii, B, 245.

2 Graham Brown, *Proc. Roy. Soc.*, 1914, lxxxvii, B, 132.

3 Lucas, *Jour. Phys.*, 1905, xxxiii, 125.

TABLE OF RESULTS.

REFLEX AND NERVE-MUSCLE CONTRACTION HEIGHTS NEAR THE THRESHOLD OF STIMULATION.

Tenuissimus muscle of the cat. Single induction shocks gradually increased in strength applied to the motor nerve ("Nerve-muscle") or to a sensory nerve for reflex contractions ("Reflex"). Cat made spinal by pithing the brain. The first three contraction heights only are listed. Magnification approximately ten times. Optical registration.

			Height of record on drum in mm.		
			1st step.	2nd step.	3d step.
I	Nerve-muscle	(2-22-22)	9	18	25
II	Nerve-muscle	(6-27-22)	7	28	42
III	Nerve-muscle	(7-10-22)	28	40	57
IV	Reflex	(7-5-22)	35	44	50
V	Reflex	(7-14-22)	15	35	46
VI	Reflex	(7-20-22)	7	12	22
	Nerve-muscle		6	10	21
VII	Reflex	(11-17-22)	3	7	14
	Nerve-muscle		4	14	....
VIII	Reflex	(11-28-22)	8	11	14
	Nerve-muscle		6	14	23
IX	Reflex	(12-1-22)	13	26	32
	Nerve-muscle		10	37	....
X	Reflex	(9-25-22)	8	24	30
	Nerve-muscle		13	35	....

ilarly stimulated and reflex contractions of the muscle obtained the records show the same step-like increments in contraction heights (Exps. IV and V).

The intervals between one contraction height and the next are of the same order of magnitude as those of the nerve-muscle preparation. Experiments VI to X are cases where the records have been obtained from the same muscle in the same animal. Exact duplication of records is not to be expected but the correspondence in height of increments is close,—notably so in Experiment VIII. Each step or increment follows the all-or-none law; if an increment appears at all it appears at its maximum. The records therefore furnish presumptive evidence that in the vicinity of the threshold, reflex contraction does not escape the limitations of the all-or-none conditions under which nerve and muscle fiber act. To this extent the results confirm those of Olmsted and Warner,[4] and are in opposition to those of Graham-Brown.[5]

[4] Olmsted and Warner, *Amer. Jour. of Physiol.*, 1922, lxi, 228.

[5] Graham Brown, *loc. cit.*