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Sensory Components of the Phrenic Nerve of the Cat.

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The presence of sensory components in the phrenic nerve was known even before Luscka[1] gave a fine description of the course and distribution of this nerve. Schreiber[2] described increases in blood pressure brought about by stimulation of the central end of the cut phrenic in dogs. In addition to the extensive treatment of the phrenic nerve by Felix,[3] a number of papers have appeared in which functions of the sensory fibers in this nerve have been investigated: Capps and Coleman,[4] Greene,[5] Pollock and Davis,[6] Hinsey and Phillips,[7] Thornton,[8] and Little and McSwiney.[9]

Ferguson's anatomical analysis[10] consisted of removal of the 3-4-5-6 C dorsal root ganglia in a cat. After a degeneration interval, he found that one-third of the myelinated fibers had undergone degeneration. This procedure is open to the criticism that possibly he traumatized some of the ventral root fibers at the time the operation was done.

Instead of degenerating the sensory fibers in the phrenic nerve, we have left them intact and have degenerated the other nerve fibers. To accomplish this, the sympathetic trunk was removed from above the superior cervical ganglion down to the lower thoracic region and the ventral roots of C 2-3-4-5-6-7-8 cervical segments were sectioned. Suitable degeneration intervals intervened before the termination of the experiments. Three preparations were made as follows:

Cat No. 59. January 15, 1937. Removed right and left superior cervical sympathetic ganglia and the sympathetic chains in the neck down through the middle cervical sympathetic ganglia. February 5, 1937.

1 Luscka, H., *Die Anatomie des Menschen*, I, Laupp and Siebeck, Tubingen, 1862.

2 Schreiber, J., *Arch. ges. Physiol.*, 1883, **31**, 577.

3 Felix, W., *Deutsche Z. f. Chir.*, 1922, **171**, 397.

4 Capps, J. A., and Coleman, G. H., *An Experimental and Clinical Study of Pain in the Pleura, Pericardium, and Peritoneum*, Macmillan Co., New York, 1932.

5 Greene, C. W., *Am. J. Physiol.*, 1935, **113**, 399.

6 Pollock, L. J., and Davis, L., *Arch. Neurol. Psychiat.* 1935, **24**, 1041.

7 Hinsey, J. C., and Phillips, R. A., *Am. J. Physiol.*, 1937, **119**, 336.

8 Thornton, J. W., *J. Physiol.*, 1937, **90**, 85.

9 Little, M. G. A., and McSwiney, B. A., *J. Physiol.*, 1938, **94**, 2.

10 Ferguson, J., *Brain*, 1891, **14**, 282.

Removed right and left thoracic sympathetic chains from above stellate ganglia to below T 7. February 26, 1937. Cut ventral roots of left C 3-4-5-6-7 spinal nerves, March 15, 1937. Animal sacrificed with ether.

Cat No. 10. September 10, 1937. Cut left ventral roots of C 2-3-4-5-6-7-8 intra- and extradurally. October 8, 1937. Removed left sympathetic chain from above superior cervical ganglion down through T 8. November 1, 1937. Animal sacrificed with ether.

Cat No. 11. September 14, 1937. Cut left ventral roots of C 2-3-4-5-6-7-8 intra- and extradurally. October 8, 1937. Removed left sympathetic chain from above superior cervical ganglion down through T 8. November 1, 1937. Animal sacrificed with ether.

The removal of the postganglionic sympathetic neurons is important in this procedure because of the fact that anastomotic branches are contributed from the sympathetic chain at the level of the stellate ganglion and above. These branches may contain myelinated sensory fibers, and myelinated as well as unmyelinated postganglionic ones. While most of the sensory fibers from the phrenic of the cat enter the spinal cord at the level of the 5th and 6th cervical segments (Little and McSwiney[9]), there is a possibility that some may enter at the 4 C level. Our dorsal root sections were either one or two segments above and below the levels at which somatic motor fibers are thought to enter the phrenic nerve. In each case, the absence of a response on stimulation of the distal portion of the cut phrenic showed that no somatic motor fibers had escaped section. The degeneration intervals were such that there seems to be little possibility that regeneration confused the picture, particularly in Cat No. 59.

Histological studies were made on the portion of the phrenic between the heart and the diaphragm. Axis cylinders were counted in silver preparations (method of Bodian) and myelin sheaths in osmic acid preparations from adjacent portions of the nerve. The diameters of the myelinated fibers were determined by measurements on photomicrographs taken with considerable magnification.

In Fig. 1, the numbers of myelinated fibers are represented by dots and the sizes are expressed in microns on the abscissae. The numbers of nerve fibers in the normal right and left phrenic nerves of an animal are not identical and consequently a comparison of the number of sensory myelinated fibers in the left operated phrenic nerve with the total number in the normal right one has its limitations. However, some rough idea of the relative number can be obtained. The normal right phrenic nerve has somewhere in the neighborhood

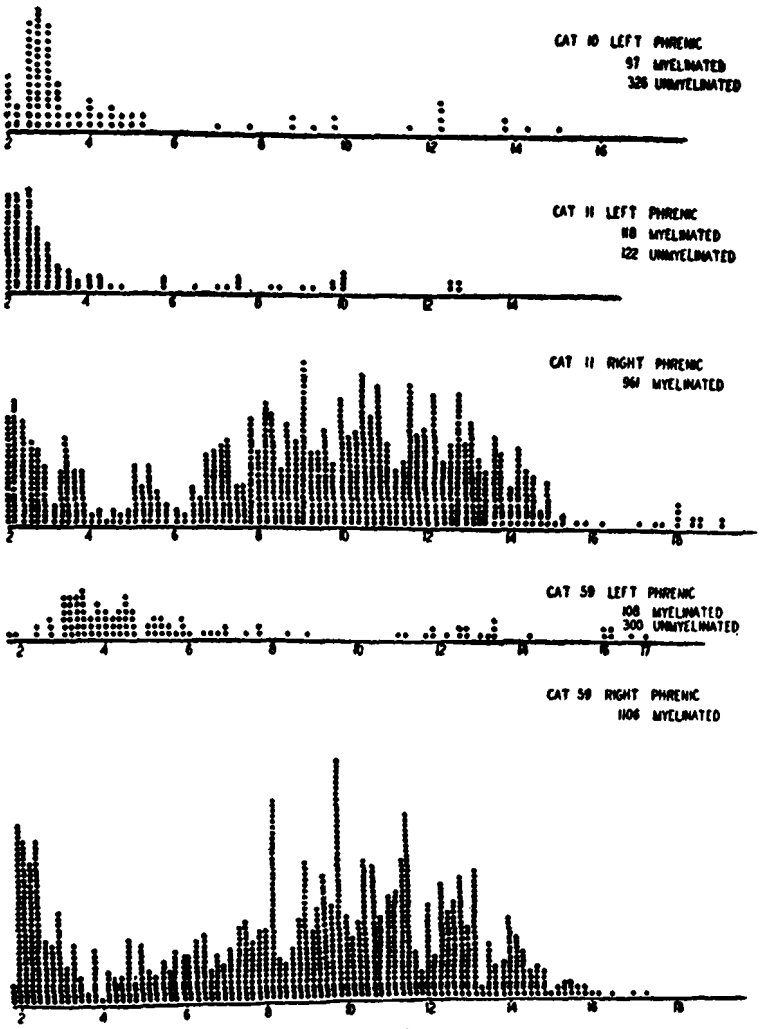

FIG. 1.

Analyses of myelinated fibers in phrenic nerves from Cats No. 10 (with only sensory fibers present), No. 11 and No. 59 (left phrenic with only sensory fibers and right one with all fibers present). Diameters of fibers represented in microns on abscissæ and each fiber by a dot on the ordinates.

of 1000 fibers and there are about 100 myelinated sensory fibers in the left operated phrenic. This indicates that approximately 10% of the myelinated fibers of the phrenic are sensory. This relationship is low when it is compared with that in a motor branch of the femoral nerve in which 30 to 40% of the myelinated fibers are sensory.

In cats No. 10 and No. 59, there were 3 unmyelinated sensory

fibers for every myelinated one while in Cat No. 11, the ratio was about one to one. However, the silver staining was more satisfactory in the first 2 than it was in the last one. A 3 to 1 ratio of unmyelinated to myelinated sensory fibers is high as compared to the one to one ratio determined by Ranson and Davenport[11] for a muscle branch of the femoral nerve. In such a comparison, it should be recalled that the portion of the phrenic nerve which has been analyzed contains sensory fibers to the central portions of the diaphragmatic peritoneum and pleura as well as the proprioceptive innervation to skeletal muscle. While the presence of muscle spindles in the diaphragm has been affirmed and denied (for review see Hinsey[12]), we have not found them in our preparations but we must admit that our search has not been extensive enough to deny their presence.

With the coöperation of Dr. Harry Grundfest of the Rockefeller Institute, action potentials were recorded from the left phrenic of Cat No. 11. The velocity of conduction in the fastest fiber was 63 m.p.s. and there was a slow wave, made up of potentials of fibers in which velocity of conduction was about 20 m.p.s. No "C" spike was observed.

Some of these sensory fibers which have been isolated are ones whose impulses are involved in the production of the sensation of pain from the central portion of the diaphragmatic peritoneum and pleura. This has been investigated by Capps and Coleman,[4] Pollock and Davis,[6] and Hinsey and Phillips.[7]

Summary. By degeneration of the somatic motor and sympathetic fibers in the phrenic nerve, it has been shown histologically that this nerve contains myelinated sensory fibers of different sizes and unmyelinated ones. The ratio of unmyelinated to myelinated sensory fibers is relatively high in 2 of the 3 phrenic nerves studied as compared to that reported for a motor branch of the femoral nerve.

11 Ranson, S. W., and Davenport, H. K., *Am. J. Anat.*, 1931, **48**, 331.

12 Hinsey, J. C., *Physiol. Rev.*, 1934, **14**, 514.