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"RECURRENT FIBRES" OF THE DORSAL ROOTS.

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IN previous work [Matthews, 1934; Barron and Matthews, 1935] we have shown that impulses may leave the spinal cord by the dorsal roots and that the fibres carrying these impulses may be physiologically classed into three groups. This paper is the report of experiments done to determine whether or not such fibres could be demonstrated histologically. On the basis of our physiological experiments we postulated that the majority of these centrifugally conducting fibres were collaterals of dorsal column fibres which extend peripherally instead of descending into the grey matter of the spinal cord.

The literature of degeneration experiments (for a review on the literature see Hinsey [1934]) contains many reports of undegenerated fibres in the central stumps of the roots; some observers have found many, others very few. If our postulate regarding the course of these fibres is correct, these discrepancies are accounted for by the different total extent of the root resection in the different observers' experiments, and the position of the central stumps relative to the denervation. Many of the fibres that leave the cord appear to have entered by other rootlets up and down the cord and have their cell station in the posterior root ganglion; hence the greater the extent of root resection the more fibres leaving by this rootlet will have been cut as they enter the cord. Therefore the greater the extent of denervation, the smaller the number of surviving fibres. However, if only a single rootlet were sectioned nearly all of the emerging fibres in it should survive (Fig. 1). This crucial experiment so far as we were aware had never been done. The reciprocal of this experiment consists in cutting all of the entering rootlets in a dorsal root except one. In this one

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intact bundle most of the emerging fibres should have been severed from their cell bodies and degenerated fibres should, therefore, appear in the tiny rootlet even though it had been untouched.

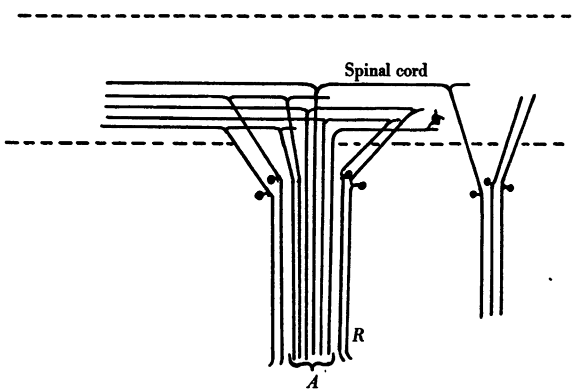

Fig. 1. Diagram to show the origin of the emergent fibres. The rootlet *A* is shown containing four fibres that have entered the cord by other rootlets of the same root, one from an adjacent root and one from an intraspinal neurone. Section of all roots central to the ganglia would leave one fibre in *A* undegenerated, section of *R* alone would leave two, and section of *A* only would leave all six.

Methods.

All of the observations have been made on the lumbo-sacral roots of cats. The spinal cord was exposed under chloroform and ether, and one rootlet on each side dissected free before being cut peripherally. In five cases a small portion of the rootlet was removed and fixed at once as a control to determine the original number of fibres in the twig sectioned. The central end of the rootlet was tied by either a silver wire or a black silk loop for identification. In one cat all of the components of the fifth, sixth and seventh posterior roots were sectioned except one small bundle in each root. These three bundles of fibres were left intact and untouched. In some cases the dura was not sutured, but the best results were obtained when it was closed with interrupted silk which prevented the resected rootlets from becoming involved in scar tissue.

In all sixteen cats recovered from the operation.

When these animals were later sacrificed some were decerebrated and the activity of the central ends of the degenerated rootlets was examined with an amplifying recording system and a loud-speaker. All of the rootlets and their controls were fixed in 1 p.c. osmic acid and sectioned in paraffin.

RESULTS.

In the rootlets examined electrically impulses were found to be conducted toward the periphery just as in the normal controls examined in adjacent rootlets. Physiologically therefore the conducting pathways demonstrated in the intact roots were still present after the degeneration which followed peripheral section of the posterior rootlets.

When examined histologically every one of the resected rootlets was found to contain large numbers of intact fibres. Their presence in the rootlets fixed thirty-two days after resection (Fig. 2) as well as in those removed only one week post-operatively (Fig. 4), coupled with their normal physiological activity, argues that they were not regenerated axons from the resected stump or the anterior root. The majority of these intact fibres were of a large diameter, but this might have been partly due to traumatic swelling.

Unfortunately it did not occur to us until late in the series that an exact numerical estimate of the proportion of these fibres present could be made by taking a short piece of the rootlet during the first operation. The earlier cats of the series show many undegenerated fibres to be present, but do not show what fraction they form of those originally present.

TABLE I. The surviving axons in the central ends of posterior rootlets 7–8 days after resection.

Cat	Surviving axons	Total	Entering axons	p.c. recurrent
5L	288	692	404	41
7R	124	445	321	28
7L	168	583	415	27
6R	156 (damaged)	2177	—	—
6L	129 (damaged)	1226	—	—
			Average	32

We are indebted to Dr J. P. Evans for his cooperation in some of the operations upon which these studies are based.

Table I lists the number of myelinated fibres in several posterior rootlets at the time of the operation and the number present in the same bundles seven to nine days after section. From these figures it was possible to arrive at an estimate of the percentage of these "recurrent fibres" in the dorsal rootlets. In the first three rootlets in the table an average of 32 p.c. of the fibres originally present in them were normal eight days after the rootlets were sectioned. The degenerated nerves of cat 6, which contained larger bundles than any of the first three in the table, unfortunately became fragmented during preparation, and large parts of the bundles were clearly missing in the sections obtained. Though many normal fibres were present in these sections, the comparative count of the portions of the bundles could not be compared with the complete controls and so cat 6 had to be omitted from the average.

The considerable variation in the percentages of surviving fibres in the different bundles may in part be accounted for by the tendency of the "recurrent fibres" to be grouped together. This tendency is illustrated by Fig. 3, in which the surviving fibres are seen to be grouped in the right-hand bundle of the rootlet. Had this rootlet been divided into its two component bundles, one would have had a low and the other a high percentage of surviving fibres.

These histological findings are in complete agreement with the schema suggested from the physiological experiments. They do not, however, demonstrate the location of the nutrient cell of these fibres, except that it cannot be peripheral to the point of section.

The results of Hinsey [1934] and earlier workers who resected whole dorsal roots demonstrate that few if any of the fibres in the dorsal root have their cell station in the spinal cord. The cell station of these fibres must, therefore, be assumed to be in the spinal ganglion. The reciprocal of our first series of experiments directly confirms this assumption. All of the rootlets of the fourth, fifth, sixth, seventh lumbar and first sacral posterior roots were cut with the exception of a single rootlet in the fifth, sixth and seventh roots respectively. These intact rootlets contained many degenerated fibres nine days later when they were removed and fixed (Fig. 5). Clearly these degenerated fibres had been severed from their cell bodies in the spinal ganglion by resection of all of the neighbouring dorsal rootlets. This is made clear by reference to Fig. 1. If all the rootlets but those marked *a* were severed, the five emergent fibres would all degenerate leaving only the normal entrant fibres (omitted from the diagram) intact.

Discussion.

All these histological results are therefore in complete agreement with the working model outlined from our physiological experiments. We are quite aware that this histological evidence alone could not be taken as crucial, as we have not made teased preparations of any of these degenerated nerves. Further, it might be objected that seven days is not sufficient time for complete degeneration and that the presence of intact fibres thirty-two days after the operation might possibly be ascribed to regeneration of some sort. However, the two lines of evidence, histological and physiological, taken together seem to establish the nature of these recurrent fibres.

Joseph [1887], and Kahr and Sheehan [1933], have described degenerated axons in the peripheral nerve beyond the spinal ganglion after section of the posterior roots. The latter authors have also described degenerated axons in muscular nerves which they concluded to be fibres whose trophic centre was in the spinal cord. We have not found electrical evidence of the existence of many fibres of this type, nor can the efferent nature of such fibres be demonstrated histologically. It seems probable that the degenerated fibres previously described in the periphery are the collaterals of the dorsal columns that have been severed from the cell body by the dorsal root section. These collaterals do not appear to be related to the spinal parasympathetic system described by Ken Kuré [1931]. They appear to be true sensory fibres conducting impulses into the cord, and behaving in general as though they had a cell station in the spinal ganglion.

Summary.

Histological evidence has been presented which suggests that in the cat collaterals of the fibres of the posterior columns pass to the periphery through the spinal ganglion without a cell station. These collaterals constitute about 32 p.c. of the fibres in the lumbo-sacral roots.

REFERENCES.

Barron, D. H. and Matthews, B. H. C. (1935). *J. Physiol.* **84**, 9 *P*.
Hinsey, J. C. (1934). *J. comp. Neurol.* **59**, 117.
Joseph, M. (1887). *Arch. Anat. Physiol.*, Lpz., Abteil. 296.
Kahr, S. and Sheehan, D. (1933). *Brain*, **56**, 265.
Kuré, K. (1931). *Über den Spinal-parasympathicus.* Basel.
Matthews, B. H. C. (1934). *J. Physiol.* **81**, 29 *P*.

EXPLANATION OF PLATE I.

Fig. 2. Cross-section of the central end of a dorsal rootlet thirty-two days after section. ×160.

Fig. 3. A section through the central end of a dorsal rootlet after thirty days' degeneration. The intact fibres are almost solely confined to one bundle. ×160.

Fig. 4. A section from the central end of a dorsal rootlet after seven days' degeneration. ×160.

Fig. 5. A cross-section of an intact dorsal rootlet containing degenerating fibres eight days after all the remaining rootlets in the same dorsal root had been sectioned. ×80.

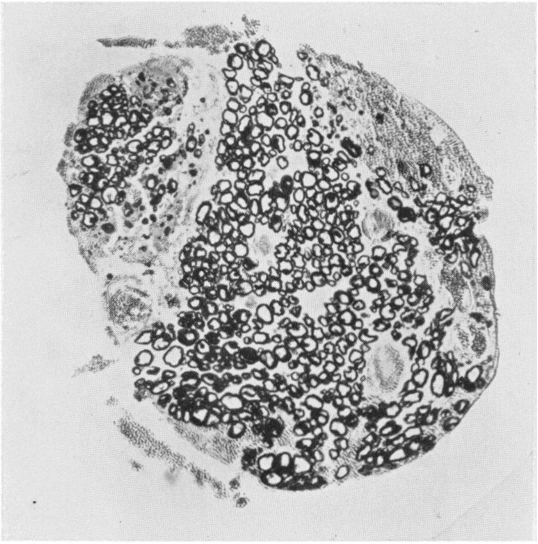

Fig. 2.

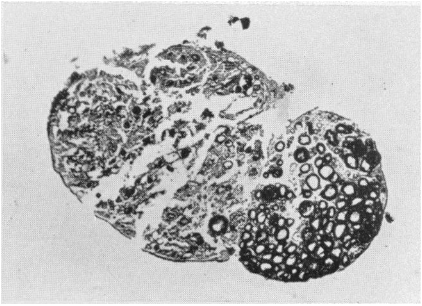

Fig. 3.

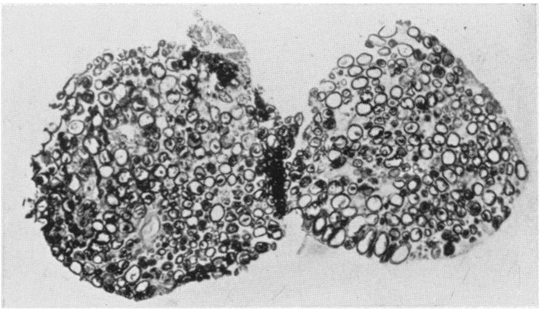

Fig. 4.

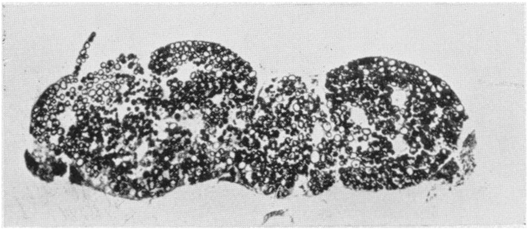

Fig. 5.

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