THE RELATION BETWEEN THE OCCURRENCE OF WHITE RAMI FIBERS AND THE SPINAL ACCESSORY NERVE.

By A. H. ROTH, A.B., M.D.,

Instructor of Anatomy in the University of Michigan.

(With an Addendum by J. PLAYFAIR MCMURRICH)

With One Figure.

In two important papers published in 1886 and 1889 GASKELL pointed out that the spinal accessory nerve in the dog contained in its upper part fine calibered fibers resembling those which formed the visceral efferent fibers of the thoracic nerves, and concluded that these fibers represented the white rami communicantes of the upper cervical nerves. Furthermore he revived, in a new form, the view propounded long before by BELL, in supposing that instead of but two roots, each segmental nerve of the body possessed in addition visceral roots, which, so far as their efferent fibers were concerned, were associated with a lateral column of cells in the central nervous system. Throughout a considerable portion of the spinal region these visceral efferent fibers form the white rami communicantes; in the cranial region they are represented by those fibers which, since the embryological studies of HIS demonstrated so clearly their distinctness, are generally known as the lateral motor roots. And since the fibers of the lower roots of the spinal accessory belong to the lateral motor series, and according to GASKELL's view the upper roots represent white rami communicantes, there follows the conclusion that a correlation should obtain between the spinal accessory nerve and the occurrence of white rami passing from the spinal nerves to the sympathetic cord.

In the dog GASKELL found in the anterior roots of the spinal nerves from the 10th to the 25th, large numbers of very fine calibered medullated fibers, their diameter varying from 1.8μ to 2.7μ with a few reaching 3.6μ. He found also that the tenth nerve, i.e., the second thoracic, in which these fibers first appeared, was the uppermost one which had a white ramus communicans connected with it and furthermore he found that this white ramus was composed almost entirely, so far as its medullated fibers were concerned, of fibers of a similar calibre to those first occurring in the anterior root of the tenth nerve. The conclusion naturally followed that the fine calibered fibers of the anterior roots were the white rami fibers and that the first group of such fibers given off from an anterior spinal root was that of the second thoracic.

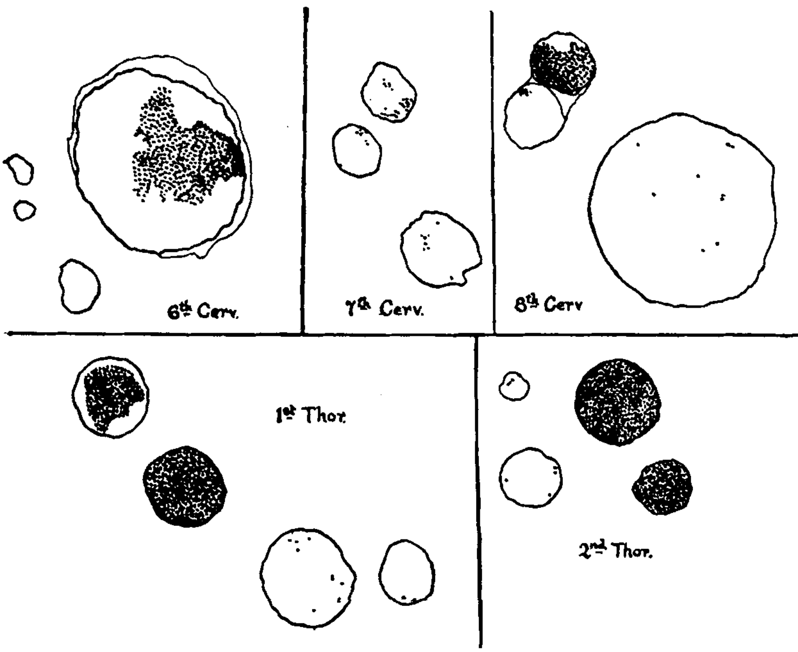
If these conclusions be correct, then it is clear that in the dog there is a distinct gap between the first nerve which possesses a white ramus and the level at which the lowest root of the spinal accessory nerve arises, this root being given off at about the level of the seventh cervical nerve, three segments above the level of the first white ramus. Such a condition does not accord with GASKELL'S view as to the significance of the spinal accessory and it seemed that it might be of interest to investigate the relations of the two structures, spinal accessory and white rami, in other mammals with a view to ascertaining whether the discord was of general occurrence or whether some correlation really existed.

For this purpose it seemed advisable to select first of all some form in which the origin of the lowest root of the spinal portion of the spinal accessory occurred at a decidedly different level than in the dog. BISCHOFF (1832) in his comparative study of the spinal accessory found that in mammals there was a considerable difference in the distance to which the nerve descended into the cervical region. Thus, he found that it descended in the weasel to about the level of the second cervical nerve; in the mole, rat and marmot to that of the third cervical; in the rabbit to that of the fifth cervical; in the stone-marten, stag, cat, wolf and man to that of the sixth cervical; and in the pig, dog, and calf to that of the seventh cervical. Having regard to these data the rat was chosen as a suitable form for study, especially as it was one readily obtained ; and a study of the distribution of small medullated fibers in the anterior roots of the cervical spinal nerves and in the rami communicantes with reference to the lowest root of the spinal accessory was made in that form. Some observations were also made upon the cat and dog, but rats fully grown, formed the principal object of study.

Before proceeding to consider the conditions in the rat it is necessary to define what is meant by a white ramus fiber. GASKELL limited the term to small fibers which were distinctly grouped in bundles, and on this basis made a special point of the occurrence of the uppermost white ramus communicans in connection with the second thoracic nerve. But is such a limitation justifiable? Must it be supposed that fibers of the same quality are always grouped together in distinct bundles? Such does not seem to be the case throughout the central system and from what is known as to the association in bundles of fibers of very different origin in both the central and peripheral systems —e. g. the so-called mesial fillet fibers with the fillet in the central system, and the chorda tympani with the lingualis fibers in the peripheral system—it would seem that the mode of grouping of fibers so far as their quality or origin is concerned, is, to some extent at least, fortuitous. It seems quite possible that when but a relatively small number of white rami fibers exist, they may not form a distinct bundle, but may be incorporated in a single trunk with grey rami fibers and may, if their number be very small, be scattered among such fibers. In other words, it is possible that the ordinary use of the terms white and grey ramus is merely relative, indicating merely the preponderance in the nerve trunk of one or the other variety of fibers.

The observations of HARMAN (1900) on the occurrence of white rami fibers in man makes this possibility very prominent and my observations upon the rami communicantes of the lower cervical and upper thoracic nerves of a dog are also of interest in this connection.

In sections of the ramus connected with the 6th cervical nerve four distinct bundles were found. Three of these were quite small, while the fourth was large, its area exceeding considerably that of the other three combined. The three small



DESCRIPTION OF FIGURE. Transverse sections of the rami communicantes of the sixth cervical to the second thoracic nerves in the dog. The outlines were traced with a camera lucida; the shaded areas represent white fibers and the unshaded grey, but no attempt has been made to represent the actual number of white fibers in the rami in which they are abundant, the eighth cervical nerve, for example, containing more white rami than the sixth in which they are interspersed with grey fibers.

bundles were wholly composed of non-medullated fibers, but the large one, though mainly non-medullated, contained imbedded in its central portion a large number, at least 250, small calibered medullated fibers. On superficial inspection, such a ramus would undoubtedly appear to be a gray ramus since the white fibers were almost entirely invested by the non-medullated ones.

The ramus of the seventh cervical nerve consisted of three bundles, two of which were entirely grey, while the third contained a few, about 25, medullated fibers. The eighth ramus consisted again of three bundles, one of which was large and grey, containing only about half a dozen small medullated fibers, the second small and almost entirely grey, while the third was almost entirely composed of white fibers, although two small groups of grey fibers occurred at its periphery. These two small bundles were fused in the upper part of the ramus. The first thoracic ramus consisted of five bundles, one of which was exceedingly small, consisting of not more than about one dozen fibers, six of which were medullated. Of the other bundles two were almost entirely grey, containing each from ten to twelve medullated fibers, while the other two were mainly white, one entirely so, the other however containing a considerable number of grey fibers. Finally in the second thoracic ramus four bundles were present, two of which were almost entirely grey, containing each only a half dozen small white fibers, while the other two were entirely white.

In connection with the second thoracic there are two bundles which may properly be designated white rami, in connection with the first thoracic one, and in connection with the three lower cervical none. But in each of the cervical rami and in an additional bundle of the first thoracic small white fibers exist which are in no wise different either in appearance or size from fibers composing recognized white rami. Only by determining the origin and termination of these fibers can it be definitely decided that they are really white rami fibers, but if there is anything to be concluded from their size and their similarity to the fibers of the white rami, then they are undoubtedly of the same nature as these latter, and they will be termed white rami fibers in what follows.

Evidence as to the nature of the fibers may be derived from physiological experimentation. The observations of NAWROCKI and PRZYBYLSKI (1891) and more especially of LANGLEY (1892) certainly do not favor the view that the fibers in question are white rami fibers, since they found that in the cat, in which the conditions are very similar to those obtaining in the dog, no dilatation of the pupil resulted from stimulation of the anterior roots of nerves above the eighth cervical, LANGLEY

(1892) indeed, obtaining no response to stimulation of roots above the first thoracic. And furthermore the latter author found no evidence of the existence of vaso-constrictor fibers for the head, of secretory fibers for the submaxillary gland or of accelerator fibers for the heart in the anterior roots of nerves above the first thoracic.

It is to be noted, however, that these results were obtained by stimulation of the anterior roots of the spinal nerves. At an earlier date FRANCOIS-FRANCK (1878), working in MAREY'S laboratory obtained quite different results by the direct stimulation of the rami communicantes. He isolated in the cat the lower cervical and upper thoracic rami, and after severing their connections with the roots of the spinal nerves stimulated each one independently, with the result that he obtained dilatation of the pupil on stimulation of the rami of all the nerves from the sixth thoracic to the fifth cervical inclusive, and he concluded that "la moelle cervico-dorsale, entre le niveau de la 5^{me} cervicale et de la 6^{me} dorsale, fournit au ganglion 1re thoracique des rameaux convergentes qui contiennent tous, en plus ou moins abondance, de filets irido-dilatateurs."

These results are clearly much more in harmony with the anatomical observations recorded above, and it becomes an interesting question to determine the cause of the discrepancy between the results which followed stimulation of the anterior roots and those following stimulation of the white rami. This question did not, however, fall within the scope of the present study as it was originally planned, and I shall now proceed to consider the relations which exist between the roots of the spinal accessory nerve and the occurrence of white rami fibers in the rat.

Observations on Rats.

In five rats the spinal cord was exposed by carefully cutting away the neural arches of the vertebrae, and the spinal accessory was then traced down the cord with the aid of a dissecting microscope. In each animal the lowest roots on both sides emerged from the cord just above the roots of the fourth cervical nerve, that is to say, somewhere about the level of the third nerve as described by BISCHOFF.

From two individuals the anterior roots of the second, third, fourth and fifth cervical nerves were removed, stained in osmic acid, imbedded, after the usual preliminary treatment, in paraffin and cut into 10 μ sections. All of the roots were composed principally of large medullated fibers, having a diameter varying from 10 to 20 μ, but in addition there could be observed in each a small number of fibers whose diameter was less than 4 μ, many of them not exceeding 2 μ. Even on superficial examination, however, it could be perceived that these small fibers were much more numerous in the lower than in the upper roots and counts which were made of the fibers with a diameter of 4 μ or less gave the following results.

Roots	Rat No. I	Rat No. II
2d cervical	130	168
3d "	105	126
4th "	380	363
5th "	432	449

It is evident then, that a sudden increase in the number of small medullated fibers occurs in the anterior root of the fourth cervical nerve, that is to say, in the nerve immediately below the emergence of the last root of the spinal accessory.

The rami communicantes were next dissected out in three other rats and placed in osmic acid. The rami which were connected with the three uppermost cervical nerves failed to show any blackening with the osmic and may consequently be regarded as composed solely of gray rami fibers. With the succeeding rami, however, the case was different, a distinct blackening taking place, and on sectioning these rami it was found that they were largely composed of medullated fibers, a considerable number being of large size, measuring from 10 to 16 μ in diameter, scattered among which were numerous fibers, arranged to some extent in groups and of the same general diameter as the small fibers of the anterior roots. Counting these, it was found that they numbered in one individual 195 in the fourth ramus and 220 in the fifth.

Comparing these figures with those obtained from a count of the anterior root fibers it will be seen that they account to a very considerable extent for the increase of small fibers in the fourth anterior root, a conclusion which may be clearly seen from the following table.

Nerve	Medullated fibers less than 4μ in diameter	Medullated fibers less than 4μ in ramus communicans
2d cervical	130—168	None
3d "	105—126	None
4th "	380—363	195
5th "	432—449	220

It must be remembered however, that the counts of the anterior root fibers and those of the white rami fibers were made upon different individuals and the results show only approximately the correlation which obtains. It seems that in the anterior roots of all the upper cervical nerves there is a considable number of small fibers whose diameter is less than 4μ, but that a sudden increase in the number occurs in the anterior root of the fourth nerve and that this increase is fairly proportional to the number of fibers of a similar size in the corresponding ramus communicans. Furthermore, this increase occurs in the first nerve below the lowest root of the spinal accessory.

Observations on Cats.

The spinal accessory of the cat, according to BISCHOFF's observations, descends to the level of the sixth cervical nerve. Concerning the occurrence of white rami fibers in this animal the anatomical data are rather scanty, notwithstanding its extensive employment in physiological experimentation.

LANGLEY, it is true, paid some attention to this side of the problem, but apparently confined his attention mainly to those rami communicantes which without microscopical examination could be recognized as composed largely of medullated fibers. He says "in the Cat and Dog, the uppermost *obvious* white ramus is that for the IInd thoracic ; but with a little trouble one, two, or three fine white strands can be seen stretching from the Ist thoracic nerve to the ganglion stellatum. When these are hardened in osmic acid and sections cut, they are seen to have the characters of white rami ; that is, they consist chiefly of small medullated fibers collected in bundles, with a few medium or medium sized fibers ; between the bundles are a variable number of non-medullated fibers ; besides these there one or more grey rami, *i.e.*, bundles consisting chiefly of non-medullated fibers, but containing scattered medullated fibers."

These results are entirely in harmony with the author's experimental observations and show a marked discrepancy between the occurrence of efferent white rami fibers and the development of the spinal accessory.

In four out of five cats examined in connection with the present study, the level of the lowest root of the spinal accessory agreed with that assigned to it by BISCHOFF, that is to say, it occurred at the level of the sixth cervical nerve. In the fifth individual, however, the nerve of the left side extended down the cord only to the level of the fifth cervical nerve, that on the right side agreeing with the findings in the other individuals.

In two of the four individuals in which the development of the spinal accessory was symmetrical in the two sides, it was found that the ramus communicans given off from the sixth cervical nerve contained a very few scattered medullated fibers. That from the seventh nerve however, contained a large number of white rami fibers. In the fifth animal, in which the development of the spinal accessory was unsymmetrical, sections were made of the anterior roots of the spinal nerves after treatment with osmic acid, but unfortunately the rami were not studied, and as regards the anterior roots, it was not found possible to make a count of the smallest fibers, which could be regarded as sufficiently accurate for record. It was certain, however that a marked increase in the number of these fibers occurred in a definite anterior root on each side and this increase was correlated with the level of the lowest root of the spinal accessory. Thus it was found that on the left side, on which the spinal accessory descended to the level of the fifth nerve, the sudden increase of small fibers occurred in the anterior root of the sixth nerve, while on the right side, in which the accessory descended to the level of the sixth nerve, the increase did not occur until the seventh nerve. These relations may be expressed in tabular form thus:

	Level of lowest root of spinal accessory.	Anterior root in which increase of small fibers occurs.
Left side	5th nerve	6th nerve
Right side	6th nerve	7th nerve

These observations in the cat are by no means so conclusive as those made upon the rat, but nevertheless they harmonize admirably with them, and the case of the fifth cat is especially interesting as showing that the correlation of the white rami fibers with the origin of the lowest root of the spinal accessory nerve occurs even in cases of individual variation.

ADDENDUM.

From the above observations there appears to be, in both the rat and the cat, a sudden increase in the number of white rami fibers in the ramus communicans of the nerve which immediately succeeds the last root of the spinal accessory nerve, and the conditions demanded by GASKELL's supposition are fulfilled. It does not, however, necessarily follow that the significance which GASKELL assigns to the spinal accessory is the correct one. It may be true that the cranial lateral motor roots are serially homologous with the visceral motor roots, i.e., the white rami fibers of the cord; indeed, there is much to recommend such a view. But that the spinal accessory, or, to be more precise, the cervical portion of that nerve, actually represents the white rami fibers of the upper cervical spinal nerves is more than doubtful.

It is becoming more and more apparent that the classification of the spinal accessory as a distinct unit in the series of cranial nerves is erroneous; it is rather merely a portion of the vagus, whose continuation down the spinal cord is no more remarkable than the downward extension of the spinal tract of the trigeminus. It is true that the fibers of the latter nerve pursue their downward course in the substance of the central nervous system, while the spinal accessory fibers emerge from the cord, but it must be remembered that in the one case the fibers in question are afferent and in the other efferent in quality. In all its morphological and physiological characters, especially when studied from the comparative standpoint, the accessory is closely related to the vagus, and the view, so strongly supported by FÜRBRINGER, that the accessory is really a portion of the vagus, its nucleus being merely a downward extension of the vagus nucleus, seems to represent the true significance of the nerve.

Whether or not the downward extension of the vagus nucleus be dependent upon the development of the trapezius and sterno-mastoid muscles, as the evidence presented by FÜRBRINGER seems to indicate, it is certain that comparative anatomy shows us a gradually increasing size of the vagus nucleus and its gradual extension into the spinal region. What the cause which determines the direction of the extension may be is at present unknown, but it is to be noted that the motor vagus nucleus is a lateral nucleus and its direct prolongation downward would therefore bring it into most intimate relation with the cell column from which the spinal white rami fibers take their origin. In its continued downward progress it may be supposed that it would gradually displace the majority of the cells of the sympathetic column throughout the spinal segments it traversed, forcing them to a lower level, so that throughout the region occupied by the extended nucleus, white rami fibers would be either wanting or few in number, while below the termination of the nucleus there would be a sudden increase in their number. This is exactly the condition which the results recorded above seem to show.

There is one point, however, which such an explanation fails to clear up, namely, the existence of a second somewhat sudden increase in the number of white rami fibers in connection with the first and second thoracic nerves. The fact that this second outflow begins at about the level of the lowest nerve participating in the formation of the brachial plexus, and that it ceases at about the level of the beginning of the lumbo-sacral plexus, has suggested its dependence in some way upon the plexuses, a view which has been especially emphasized by HARMAN with reference to the upper limits of the outflow. The exact significance of the interdependence remains, however, obscure; but granting its existence, it still leaves room for the significance which has been assigned above to the upper outflow, and it would seem that there are two factors influencing the occurrence of white rami fibers in the cervical region, one of which is the development of the spinal accessory nerve, while the other is associated with the development of the brachial plexus. J. PLAYFAIR MCMURRICH.

Literature.

T. L. W. Bischoff.
1832. Nervi Accessorii Willisii Anatomia et Physiologia. *Heidelbergae.* 1832.

Francois Franck.
1878. Sur l'innervation de l'iris. Marey's *Travaux de Laboratoire*, IV.

M. Fürbringer.
1897. Ueber die spino-occipitalen Nerven der Selachier und Holocephalen und ihre vergleichende Morphologie. *Gegenbaur's Festschrift*, 1897.

W. H. Gaskell.
1886. On the Structure, Distribution and Function of the Nerves which innervate the Visceral and Vascular Systems. *Journ. of Physiol.*, VII, 1886.
1889. On the Relation between the Structure, Function, Distribution and origin of the Cranial Nerves, together with a Theory of the Origin of the nervous System of Vertebrates. *Journ. of Physiol.*, X, 1889.

N. B. Harman.
1900. The Anterior Limit of the Cervico-thoracic visceral efferent Nerves in Man. *Journ. of Anat. and Physiol.*, XXXIV, 1900.

J. N. Langley.
1892. On the Origin from the Spinal Cord of the Cervical and Upper Thoracic Sympathetic Fibers, with some Observations on white and gray Rami Communicantes. *Philos. Trans. Roy. Soc.*, CLXXXIII., 1892.

F. Nawrocki and J. Przybylski.
1891. Die pupillenerweiternden Nerven der Katze. *Arch. f. Physiol.*, L, 1891.