SYMPATHETIC RAMI IN MAN

By JOSEPH PICK and DONAL SHEEHAN

From the Department of Anatomy, New York University College of Medicine

In a previous communication (Sheehan & Pick, 1943) we reported on the connexions and constitution of the rami communicantes in the rhesus monkey. Four general types of sympathetic branches were differentiated according to their fibre content: Type I representing the white rami, Types IIA and IIB, two varieties of grey rami differing from each other according to the number of fine medullated fibres contained within each, and Type III which included the truly mixed rami. The fine myelinated fibres (under 3 μ in diameter), which were present to some extent in all grey rami, occurred in particularly large numbers in the grey rami of C8 and T1 and of L6 and L7 spinal nerves. Their abundance in these regions, namely, above and below the thoraco-lumbar outflow, attracted our special attention, and it seemed important to find out whether a similar arrangement existed in man.

A review of the literature revealed that, although the topographical anatomy of the human sympathetic chain had been frequently studied (more recently in the cervical region by Axford (1928), Siwe (1931), Laubmann (1931), Sheehan (1933), Kirgis & Kuntz (1942), and in the lumbo-sacral region by Romankevič (1930), Labbok (1932, 1937), Trumble (1934), Fagarasanu (1938), yet there were few histological investigations reported, none of which were complete. The first, and still the best, study of the constitution of the human sympathetic rami, following the discovery of the thoraco-lumbar outflow, was made by Harman (1898–1900). Using the osmic acid stain on teased preparations he examined only the rami of C5 to T4 and of T11 to L4 inclusively. In the rami of C5, C6, C7 and C8, and again of L3 and L4 (i.e. above and below the levels of the sympathetic outflow) he observed myelinated fibres 'under 4 μ in diameter', but never more than 30 at any one spinal level. It is, of course, difficult to make accurate counts of medullated fibres in teased preparations, and even Harman's enumeration of the small myelinated fibres in the rami of the thoraco-lumbar outflow is far below what we now know to be present. It is curious that Harman does not specifically differentiate between grey and white rami in the thoraco-lumbar region.

The histological appearance of the human sympathetic rami received only brief mention in the account by Müller (1909), although he evidently made Weigert-stained preparations of many of the spinal nerves and rami communicantes. His illustrations, though clearly demonstrating the existence of white, grey and mixed rami, give no indication of their constitution at different segmental levels. The rami of C8 and T1 in man were specially examined by Johnson & Mason (1921), but they were primarily interested in determining which was the uppermost white ramus and not in the appearance of the grey rami. Kiss & Mihálik (1929) from quite an extensive study, having arrived at the conclusion that there was no clear distinction between white and grey rami (both containing myelinated and unmyelinated fibres), did not proceed to give any description of the constitution of the various rami, and the first, and apparently the only, complete series of sympathetic branches examined in man was that reported by Juba (1930) from Weigert stained material. The wide distribution of medullated fibres, many of the smallest calibre, within the rami of the cervical and lower lumbar nerves was very evident. Although detail regarding each ramus is lacking from the text, it is clear from the illustrations that the ramus to S1, for example, contains several hundred fine myelinated fibres. The rami from the upper cervical region are sketched to show comparable numbers of medullated fibres, but here they are evidently of much larger size.

Botár (1932), Woollard & Norrish (1933), and others, have examined at various times the constitution of some of the sympathetic branches in man, but there is lacking from the entire literature any complete account of the rami at all levels, as we have for the monkey and lower animals (dog, cat, rabbit).

MATERIAL AND METHODS

Specimens of human rami, adequate for detailed histological study are, of course, not easily obtainable. For purposes of identifying each ramus a long and tedious dissection is essential and this is obviously difficult to undertake following a routine autopsy, and dissecting room material, even from still-births, is generally unsatisfactory for subsequent microscopical study of the nervous system. We were fortunate to obtain two cadavers injected intravascularly with 10% formol-saline shortly after death. Complete dissections with the aid of magnification were made in one specimen of the entire sympathetic chain and all its branches on both sides, in the other the same as far down as the tenth thoracic ganglion (below this level dissection was impossible). The dissections were then drawn diagrammatically, but in complete detail and every ramus labelled by number. Subsequently, all sympathetic branches were removed and placed in 10 % formol-saline for 24 hr., washed and stained in bulk in 1 % osmic acid, and sectioned in paraffin. This material was supplemented by other examples of particular rami, mostly from the upper and lower levels of the thoraco-lumbar outflow, which were removed from eight other subjects where post-mortem examination was undertaken a few hours after death. Careful identification of such rami was made in every instance.

In order to have as a guide a basic plan of the number and distribution of the rami and of the commoner variations encountered, 25 other dissections were completed and sketched, each of an entire sympathetic chain together with all its rami to spinal nerves. All except two of these were made on foetal material. One foetus was anencephalic. The statistical data concerning general topography have all been compiled from this series of twenty-five dissections.

GENERAL TOPOGRAPHY AND NOMENCLATURE

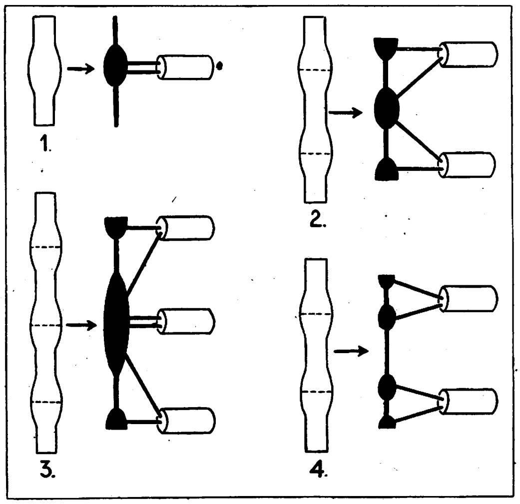
Irregularity in the number of ganglia along the sympathetic chain is a familiar observation. Anatomical texts refer to 'ten or eleven' thoracic ganglia, 'four up to eight' lumbar, and 'three or four' sacral ganglia, 'though fusion with neighbouring ganglia may reduce the number still further'. This does not, however, tell the full story, for the process of fusion is not simply a combination of adjacent ganglia. Certainly in the lower thoracic and in the lumbar region, where irregularity is even more marked in man than in the monkey, there is, if we have interpreted the facts correctly (Sheehan & Pick, 1943), division of each primordial ganglionic mass* into cranial and caudal portions, the ultimate fate of which will determine the number and the type of ganglia to be found at that particular segmental level (Text-fig. 1):

* According to Kuntz (1920) the primordia of the sympathetic trunks arise in human embryos about 5 mm. in length as small groups of cells lying segmentally along the dorso-lateral aspects of the aorta in the lower thoracic and upper abdominal regions. In embryos 9–10 mm. in length the sympathetic primordia are present from the upper cervical to the sacral regions, but due to the curvature of the embryo they are in such close proximity to each other as to appear as a continuous column of loosely aggregated cells. Secondary segmentation occurs at a later stage. In the cervical region there occurs a gradual extension cephalad of the cells constituting the sympathetic primordia of the upper thoracic region, but whether each cervical segment makes its contribution of cells to these primordia is still uncertain. There appears to be no account of the development specifically of the lumbo-sacral portion of the sympathetic chain. A further study of the ganglion crests of this region in relation to the sympathetic primordia is needed.

(1) The two portions may fuse together again (or never really separate) producing a single ganglion with connexions to only one spinal nerve, a type of ganglion truly segmental and most commonly seen in man in the upper thoracic region.

(2) A second possibility would be the fusion of the caudal half of one primordial mass with the cranial half of the next lower, forming a ganglion with connexions to two spinal nerves; therefore not strictly segmental and found typically in the lower thoracic region in man.

(3) A third possibility would be a variation of the second, namely a fusion of portions of more than two primordial masses. All combinations are possible and therefore all types of ganglia with connexions to three or more spinal nerves. This arrangement is represented typically by the superior



Text-fig. 1. Schema illustrating the development of possible variations of the ganglionic chain from the primordial cell column.

and inferior cervical ganglia and occurs quite commonly in the lumbar region in man.

(4) A fourth arrangement would result from one or both of the portions of the primordial mass persisting as a separate ganglion, thus producing additional ganglia or complete duplication.

(5) Lastly a primordial mass, or a portion of it, may appear to be missing altogether, when the rami usually connected with it come off the sympathetic chain directly.

All these varieties can therefore be recognized if the ganglia are numbered in accordance with the distribution of the rami. Indeed it is the only method of determining the proper enumeration of the ganglia and of making a true comparison between several dissections. Emphasis has been laid on this point since the confident statements in surgical literature regarding the removal of the 'third' or the 'fourth' lumbar ganglion are unintentionally misleading. To designate arbitrarily, as some have done, a ganglion lying on the body of the third lumbar vertebra, for example, as the 'third lumbar' ganglion, has no merit, for in the next case a similarly placed ganglion may bear no resemblance whatever in the distribution of its rami and indeed may have no connexion at all with the third lumbar spinal nerve.

A detailed account of the topographical anatomy of the human sympathetic chain need not be recorded here, but with the schema of development (outlined above) in mind, the following brief analysis of the ganglia and rami has been made for purposes of orientation (see Pl. 1). The *superior cervical ganglion*, large and fusiform, extended in every instance from the base of the skull to the level of the upper (or lower) border of the second cervical vertebra.

Rami*:	With C1 and C2 (incl. loops of) (cervical plexus)	11 inst.
	With C1, C2, and C3	11 inst.
	With C1, C2, C3, and C4	3 inst.

The upper two cervical nerves received two, three and occasionally four rami each. The ramus to C3 often formed a loop with a lower ramus from the sympathetic chain, and from this loop fine branches passed to C3 and sometimes to C4. In almost half the cases C3 was omitted from the distribution of the superior cervical ganglion and formed its only connexion with the cervical sympathetic chain lower down; twice it received no apparent sympathetic connexion at all.

The *middle cervical ganglion* was very variable in its occurrence, size and form; sometimes single, in others double, sometimes of medium size, in others only represented by a tiny ganglionic knot. In one example (no. 13L), an anencephalic foetus, the entire cervical sympathetic chain consisted of a fused ganglionic mass uniting the superior and inferior cervical ganglia:

Occurrence:

Absent	5 inst.
Single	10 inst. (incl. no. 13L).
Double	10 inst.

Position:

When single:	*either*	'High' position (C5)	7 inst.
	or	'Low' position (C7) (on posterior loop of ansa†)	2 ,,
When double:	*either*	Both above ansa (C5)	3 inst.
	or	One above ansa (C5), one on posterior loop of ansa† (C7)	7 ,,

* Only the rami communicating with spinal nerves are here considered.

† Sometimes referred to as the 'vertebral' ganglion and included as part of stellate configuration.

Rami:

When single: to C4, C5 and C6 (occasionally C3).
When double: upper ganglion—to C4 and C5.
lower ganglion—to C6 (occasionally C7).

There were often two or three rami to each spinal nerve and frequent interconnexions and loops between the rami. Some of the sympathetic branches, particularly those to C4 and C5, pierced the prevertebral muscles to reach the spinal nerve (designated as 'ramus profundus' by Wrete, 1934).

The *inferior cervical ganglion* was fusiform or stellate in shape and in many examples was partially or completely fused with the first, and occasionally second, thoracic ganglia.

Occurrence:

Independent	5 inst.
Fused with first thoracic ganglion	17 ,,
Fused with first and second thoracic ganglia	3 ,,

Position:

At level of intervertebral disc C7–T1.
When fused with first thoracic—extended down to intervertebral disc T1–T2.
When fused with first and second thoracic—extended down to T2 vertebral body (lower border).

Rami:

Where independent—to C6, C7 and C8 (occasionally C5).
When fused with first thoracic—to T1 and T2 in addition.
When fused with first and second thoracic—to T3 in addition.

The number of rami to each cervical spinal nerve was very variable, there being 2, 3 or 4 branches to each nerve, and frequently these arose from a common trunk e.g. the 'vertebral' nerve. (For details of arrangement see Sheehan, 1933.) The first thoracic nerve invariably received two and often three short stout rami, one of which entered the nerve medial, the others lateral, to the ganglion. They were designated as 'proximal' and 'distal' according to their points of junction with the spinal nerve, relative to one another. The contribution from T2 to the brachial plexus almost invariably received a special ramus from the lower part of the 'stellate' ganglion.

The *first thoracic ganglion* was only distinguishable as an independent ganglion in five instances. As such it was of medium size and was placed opposite the body of the first thoracic vertebra or the intervertebral disc T1–T2. Its rami were usually three short stout branches to T1 and a fine single branch down to T2, which often joined the contribution from that nerve to the brachial plexus.

The *second thoracic ganglion* was independent of the stellate in 22 instances although in 7 of these examples the connecting sympathetic chain was almost as thick as the ganglion itself. It was placed opposite the lower border of T2 vertebral body or the intervertebral disc T2–T3. Its rami were two (occasionally 3) stout branches to T2 and in 4 instances an additional slender branch to T3.

The *thoracic ganglia 3rd–10th showed a regular* segmental pattern, though some partial fusion or merging of individual ganglia occurred in a few instances, e.g.

Between	3rd and 4th	thoracic	3 inst.
,,	4th and 5th	,,	5 ,,
,,	5th and 6th	,,	1 ,,
,,	6th and 7th	,,	1 ,,
,,	7th and 8th	,,	4 ,,
,,	8th and 9th	,,	2 ,,
,,	9th and 10th	,,	2 ,,

(In two examples, no. 13R and no. 13L, there was almost one ganglionic mass between the 3rd and 7th thoracic.) Even where such merging existed the individual segmental ganglia were easily distinguishable. They were of medium size, becoming distinctly larger below the 5th or 6th thoracic, i.e. at the levels of exit (and entry) of the splanchnic nerve fibres.

Position: opposite intervertebral disc between corresponding and next lower vertebrae, or at the level of the upper border of next lower vertebra, e.g. 5th thoracic ganglion at level of intervertebral disc T5–T6 or at upper border of T6 vertebral body. Thus the thoracic ganglia were placed slightly lower than the corresponding nerve and the rami, short and relatively stout, passed obliquely upwards from the ganglion.

Rami: Two or three (rarely four) short branches* to the corresponding nerve, one usually travelling upwards and medially, the others upwards and laterally, from the ganglion.

Each ganglion occasionally supplied an additional ramus to the next lower spinal nerve, such an arrangement occurring in the following frequency:

At	3rd	thoracic ganglia	2 inst.
,,	4th	,, ,,	2 ,,
,,	5th	,, ,,	0 ,,
,,	6th	,, ,,	3 ,,
,,	7th	,, ,,	3 ,,
,,	8th	,, ,,	4 ,,
,,	9th	,, ,,	5 ,,
,,	10th	,, ,,	14 ,,

Out of a total of only twenty-five dissections these numbers have not in themselves any special significance, but the increasing frequency towards the lower end of the thoracic chain has a definite meaning, for the pattern of ganglion is the one typically found in the upper lumbar region.

The *last thoracic ganglia*. There were one or two thoracic ganglia below the tenth, according to the form of splitting and subsequent fusion which takes place in the primordial ganglionic mass. Thus in 7 instances there was a small ganglion connected only with T11 spinal nerve, and in 4 others there was a small ganglion connected only with T12 spinal nerve. These small 'extra' ganglia were present in addition to a larger ganglion connected with both T11 and T12 and designated here simply as the 'last thoracic'. It was usually placed on the body of the twelfth thoracic vertebra and was sometimes fused with the ganglion above (3 inst.) or below (4 inst.) or both (3 inst.). It was only present therefore as an independent ganglion in a little over half the specimens studied.

The *lumbar ganglia* in man were so irregular that identification and enumeration were often very difficult, much more so than in the monkey. Such wide fusion occurred in some instances that the greater part of the lumbar chain consisted of a single elongated ganglionic mass. It would be of little value to record that the number of ganglia in the lumbar region varied from two to six, with four or five occurring in over three-quarters of the cases. The type of fusion is so different from case to case that two examples with four ganglia each may bear no resemblance. Anatomically the soundest way is to break down the various fused chains of ganglia which occur in the lumbar region into their component primordial masses, according to their communicating branches, but it will be readily seen that such a plan would be of little service to the surgeon. We have therefore enumerated the lumbar and sacral ganglia according to the pattern followed in the previous study on the monkey (Sheehan & Pick, 1943), since also in man it reveals the commonest type of ganglion found independently at most levels. The frequency of massive fusion, however, must place on guard the surgeon seeking for any specific lumbar ganglion. With this fully in mind, the following analysis of the lumbar and sacral ganglia has been made. The statistics from such a small series (a total of twenty-five dissections) have only relative merit, but serve to indicate general tendencies in one direction or another.

First lumbar ganglion, i.e. with connexions to T12 and L1 spinal nerves. Present as an independent ganglion in 13 instances and then placed on the first lumbar vertebra or the intervertebral disc below. In other examples it was recognizable but fused with the ganglion above (3 inst.) or below (4 inst.) or both (3 inst.), and was accordingly displaced. In the remaining two examples its component primordial parts were separate and remained as independent ganglia or were fused with the next adjoining ganglion; no examples, however,

* The variation in number of rami to each spinal nerve is not of great significance for they differed so greatly in thickness in different dissections, and splitting and joining of rami were so common.

were found of a ganglion connected only with the first lumbar nerve.

Second lumbar ganglion, i.e. with connexions to L1 and L2 spinal nerves. Present as an independent ganglion in 12 instances, and placed on the second lumbar vertebra or the intervertebral disc below. In other examples it was recognizable, but fused with the ganglion above (6 inst.), or below (1 inst.), and was accordingly displaced. It was apparently missing in 2 instances and in the remaining 4 examples its component primordial parts were 'split' as indicated above for the first lumbar ganglion; no examples, however, were found of a ganglion connected only with the second lumbar nerve.

Third lumbar ganglion, i.e. with connexions to L2 and L3 spinal nerves. Present as an independent ganglion in only 2 instances (situated on third lumbar vertebra), but distinguishable in many others, fused with the ganglion above (2 inst.), below (8 inst.) or both (7 inst.) and accordingly displaced. In the remaining 4 examples it was 'split' as indicated above for the first two lumbar ganglia, and 3 examples altogether were found of a ganglion connected only with the third lumbar nerve.

Fourth lumbar ganglion, i.e. with connexions to L3 and L4 spinal nerves (or only L4). Present as an independent ganglion connected with both nerves in only 1 instance (situated on fourth lumbar vertebra), but distinguishable in several others, fused with the ganglion above (2 inst.), below (6 inst.) or both (4 inst.) and accordingly displaced. In 12 examples (almost half of the cases) its component primordial parts were separate and remained as independent ganglia or were fused with the next adjoining ganglion. Thus 11 examples were found of a ganglion connected only with the fourth lumbar nerve, and this must be considered its commonest form.

Fifth lumbar ganglion, i.e. with connexions to L4 and L5 spinal nerves (or only L5). Present as an independent ganglion connected with both nerves in only 4 instances (situated on fifth lumbar vertebra), but distinguishable in a few others, fused with the ganglion above (1 inst.), below (1 inst.) or both (1 inst.). In 18 examples its component primordial parts were separate and remained as independent ganglia or were fused with the next adjoining ganglion; altogether 15 examples occurred of a ganglion connected only with the fifth lumbar nerve, obviously the commonest form at this level. Such examples (like those of the fourth lumbar) differ from the truly segmental pattern seen in the thoracic region for they usually represent only one part of the original segmental primordial mass.

The *sacral ganglia*, with the exception sometimes of the first, were very much smaller than any others in the sympathetic chain. On the whole they tended to follow the pattern described for the lumbar ganglia, but there was an increasing frequency for the occurrence of a ganglion connected by a single ramus with only one spinal nerve.

First sacral ganglion:
Connected with L5 and S1 spinal nerves 13 inst.
(in 5 of these examples, fusion above or below)
Connected with S1 alone 12 inst.

Second sacral ganglion:
Connected with S1 and S2 spinal nerves 14 inst.
(in 5 of these examples, fusion above or below)
Connected with S2 alone 11 inst.

Third sacral ganglion:
Connected with S2 and S3 spinal nerves 13 inst.
(in 3 of these examples, fusion above or below)
Connected with S3 alone 12 inst.

Fourth sacral ganglion (missing altogether once):
Connected with S3 and S4 spinal nerves 17 inst.
(in 16 of these examples, fusion above or below)
Connected with S4 alone 7 inst.

Fifth sacral ganglion (missing altogether 6 times):
Connected with S4 and S5 spinal nerves 13 inst.
(in 10 of these examples, fusion above or below)
Connected with S5 alone 6 inst.

Ganglion Impar. Out of 12 cadavers, it was present 9 times: 6 times in the midline, 3 times at the end of the right chain. It distributed fine branches to the coccygeal nerves.

Intermediary ganglia, namely, ganglia placed along the course of a ramus, were surprisingly common, occurring somewhere along the sympathetic chain in practically every dissection. They were most frequently found in the cervical and lower lumbar regions, in the former quite small, but in the latter attaining the size of and sometimes replacing the segmental ganglion of the chain. The frequency at various levels is worth recording, since with such an arrangement lumbar sympathectomy as generally performed would leave these ganglia intact. Intermediary ganglia were found:

On ramus to	C4	4 inst.
,,	C5	1 ,,
,,	C6	2 ,,
,,	T10	1 ,,
,,	T12	1 ,,
,,	L1	1 ,,
,,	L2	1 ,,
,,	L3	4 ,,
,,	L4	6 ,,
,,	L5	8 ,,
,,	S2	1 ,,

A *double* (or occasionally triple) *sympathetic chain*, though extremely common and occurring anywhere in the thoracic, lumbar or sacral regions, apparently does not present any common surgical problem for it never extended in any of the dissections for more than the distance between two adjacent ganglia. This was true also in the monkey. *Transverse interconnexions* between the sympathetic chain of one side with that of the other, are equally of little if any surgical significance, for in this study they never occurred above the 5th lumbar level and were almost entirely confined to the terminations of the chains over the ventral surface of the sacrum. They were here quite common (in 9 out of 12 cadavers) and formed thin connecting branches between the ganglia or chains of each side, just above the ganglion impar. The illustrations given in some older texts of rich anastomoses between the two sympathetic chains all the way down, we believe to be erroneous.

The *origin of the splanchnic nerves* from the sympathetic chain was noted in most of the dissections; the uppermost branch emerged:

From	4th	thoracic ganglia	1	inst.
,,	5th	,, ,,	2	,,
,,	6th	,, ,,	11	,,
,,	7th	,, ,,	7	,,
,,	8th	,, ,,	4	,,

Below the twelfth thoracic vertebra, similar branches known as the 'lumbar splanchnics' passed also to the coeliac plexus. These left the sympathetic chain at many points as far down as the third lumbar vertebra in almost every example.

CONSTITUTION OF RAMI

Classification of the human rami, according to their fibre constitution, into the four types already described in the monkey (Sheehan & Pick, 1943), was such an obvious and relatively simple process that the validity of the types was more than ever apparent. The two varieties of grey rami (Pl. 2, figs. *c*, *d*) stand out in sharp contrast with the white and mixed rami (Pl. 2, figs. *a*, *e*), giving no support whatever to the contention of Kiss and Mihálik (1929) that the rami cannot be differentiated histologically. In man, as in the monkey, the white rami (type I) consisted of myelinated fibres of all sizes, ranging up to 15–20 μ in diameter, and the smallest fibres (3 μ and less) by no means dominated the picture. Again, the mixed rami (type III) showed a single nerve bundle containing areas typical of type I and others resembling closely the grey rami of type IIA.

The analysis, according to fibre constitution, of the various rami of each spinal nerve, has been condensed in Tables 1–3, in which, for the sake of clarity the letter '*w*' stands for type I (white ramus), '*m*' for type III (mixed ramus), '*g*' for type IIA (characteristic grey ramus), and '*G*' for type IIB (grey ramus heavily 'peppered' throughout with small medullated fibres under 3 μ in diameter and several hundred in number).

The limits of the thoraco-lumbar outflow can be seen at a glance at Tables 1 and 3. In Table 1 the upper level has been defined in six instances at T1. Mixed rami appear for the first time in the branches connected with this nerve, and typical white rami in those connected with T2. In two examples (PII.R and PII.L) one of the distal rami to C8 showed the appearance of type IIA grey ramus with the characteristic area of ten to twenty large and medium myelinated fibres (10 to 5 μ in diameter) near its circumference, but in this area, which was relatively insignificant in extent, a number of fine medullated fibres under 3 μ in diameter could be seen. It appeared therefore as a possibility that this represented a mixed ramus (type III) connected with the eighth cervical nerve, which would constitute a higher thoraco-lumbar outflow in this one case (the dissections were from the right and left sides of the same subject). In Table 3 the lower level of the thoraco-lumbar outflow has been defined in all seven instances at L2. This definition of the outflow (T1–L2) from a microscopical study of the rami confirms therefore the results obtained from examination of the ventral spinal roots in man (Sheehan, 1941).

An observation made in the monkey, that the white ramus to T1 is that which joins the nerve most distally, has been confirmed in man. Table 2 reveals that this is no exception, but the rule, for most of the rami of the thoracic region. This is all the more surprising since the diagrams in every standard textbook show the opposite arrangement. In the lower thoracic and upper lumbar region the spinal nerves are connected generally by at least two rami, an upper one running transversely or descending slightly from the ganglion of the corresponding segment, and a lower one passing obliquely between the nerve and the ganglion of the next lower segment. Botár's observation (1932) that the 'transverse' rami are grey and the 'oblique' rami are white is amply confirmed by the findings recorded in Tables 2 and 3 where there are only two clear reversals of this arrangement.

The frequent occurrence of type IIB (indicated by '*G*' in Tables 1 and 3) in the rami of C7, C8 and in the vertebral nerve and again in the rami of L4, L5 and S1 signifies the relative abundance at these levels of fine myelinated fibres (under 3 μ in diameter). The fact that a similar distribution of this type of grey ramus exists in the cat and monkey, indicates some fundamental pattern, but what its significance may be is not yet clear. The nerves in question are distributed particularly to the blood-vessels and sweat glands in the hand and foot, which are notoriously rich in their sympathetic innervation.

The rami marked with an asterisk in Table 1 contain relatively large areas, and in some cases separate bundles, of large and medium-sized myelinated fibres (10–5 μ in diameter). It will be

Table 1. *Types of rami communicantes of cervical and upper thoracic spinal nerves*

Dissection catalogue no.	C1 all rami	C2 all rami	C3 all rami	C4 all rami	C5 all rami	C6 all rami	C7 Prox.	C7 Dist.	Verteb. nerve	C8 Prox.	C8 Dist.	T1 Prox.	T1 Dist.	T2 From Stellate	T2 Prox.	T2 Dist.
PI.R.	*g*	*g*	—	*g*	*g**	*g**	*g*	*G*	*G*	*G*	*G* *g*	*g* *g*	*m* *m*	*m* *w*	*g*	*m* *w*
PI.L.	*g**	*g**	*g**	*g*	*g**	*g**	*G*	*G*	*G*	*G*	*G* *g*	*g* *g*	*m* *g*	*m*	*g*	*w* *m*
PII.R.	*g**	*g**	—	*g**	*g**	*g**	*g*	*g*	*g*	*g*	*g* ? *m*	*g* *g*	*m* *g*	—	*g*	*m*
PII.L.	—	*g*	*g*	*g*	*g*	*g**	*g*	*g**	*g*	*g*	*g* ? *m*	*m* *g*	*m* *g*	*w*	*g*	*m*
E.R.	—	—	—	—	—	—	*G*	*G*	*G*	*G*	*G* *g*	*G*	*m*	*w*	*g*	*w*
G.R.	—	—	—	*g*	*g*	—	—	—	*g*	*g*	*g*	*G*	*m*	—	—	—

w = Type I (white ramus). *m* = Type III (mixed ramus). *g* = Type II A (grey ramus). *G* = Type II B (grey ramus).
Where two (or more) separate nerve bundles in any ramus or two parallel rami—the constitution of both is indicated.

Table 2. *Types of rami communicantes of thoracic spinal nerves*

Dissection catalogue no.	T3 Prox.	T3 Dist.	T4 Prox.	T4 Dist.	T5 Prox.	T5 Dist.	T6 Prox.	T6 Dist.	T7 Prox.	T7 Dist.	T8 Prox.	T8 Dist.	T9 Prox.	T9 Dist.	T10 Transv. from T9 gangl.	T10 Obliq. from T10 gangl.	T11 Transv. from T10 gangl.	T11 Obliq. from last T. gangl.	T12 Transv. from last T. gangl.	T12 Obliq. from L1 gangl.
PI.R.	*m*	*w*	*g*	*m* *g*	*g*	*w* *g*	*g*	*w* *g*	*g*	*w*	*g*]	*w*	*g*	*m*	*g*	*m*	*w* *g*	*w* *m*	*g*	*w*
PI.L	*g*	*w*	*g*	*m* *g*	*g*	*w* *g*	*g*	*w*	*g*	*w*	*g*	*m*	*g*	*w*	*g*	*w* *m*	*g*	*w* *m*	*w*	*w*
PII.R.	*g*	*m* *g*	*g*	*m*	*g*	*w*	*g*	*w* *g*	*g*	*m*	*g*	*w* *g*	*g*	*w*	*g*	*m*	—	—	—	—
PII.L.	*g*	*m* *g*	*g*	*m*	—	*m*	*g*	*m*	*g*	*w*	*g*	*w*	*g*	*w*	*g*	*w* *g*	—	—	—	—
K.R.	—	—	—	—	—	—	—	—	—	—	*g*	*w*	*g*	*w*	*g*	*m* *g*	*g*	*w* *m*	*w* *g*	*w*

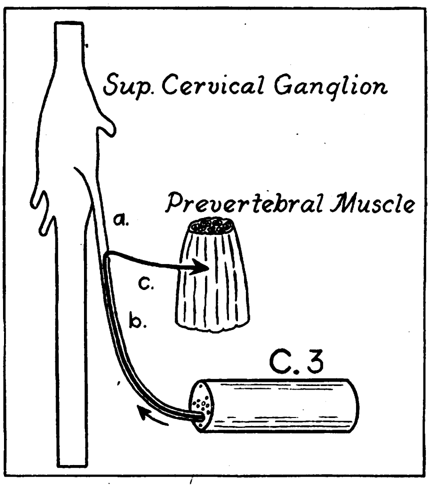
w = Type I (white ramus). *m* = Type III (mixed ramus). *g* = Type II A (grey ramus). *G* = Type II B (grey ramus).
Where two (or more) separate nerve bundles in any ramus or two parallel rami—the constitution of both is indicated.

Table 3. *Types of rami communicantes of lumbar and sacral spinal nerves*

	Spinal nerves											
	L1		L2									
Dissection catalogue no.	Transv. as from L1 gangl.	Obliq. as from L2 gangl.	Transv. as from L2 gangl.	Obliq. as from L3 gangl.	L3 all rami	L4 all rami	L5 all rami	S1 all rami	S2 all rami	S3 all rami	S4 all rami	S5 all rami
PI. R.	g	w w w	g g	w	g	g	G	G	g	g	g	g
PI. L	—	w	g	m	g	g	g	G	g	g	g	—
B. R.	—	—	g	m	g	g	G	—	—	—	—	—
T. R.	g	w	m g	g	g	G	—	—	—	—	—	—
S. R.	g	w m	m	g	g	g	G	—	—	—	—	—
E. R.	g	w g	g	w m	g	g	—	—	—	—	—	—
K. R.	g	m	g	—	g	g	g	—	—	—	—	—

w = Type I (white ramus). *m* = Type III (mixed ramus). *g* = Type IIA (grey ramus). *G* = Type IIB (grey ramus). Where two (or more) separate nerve bundles in any ramus or two parallel rami—the constitution of both is indicated.

noticed that such rami occur exclusively in the cervical region well above the thoraco-lumbar outflow. The exact course of these myelinated fibres has been traced in several examples, as indicated in Text-fig. 2, and shows conclusively that they are in reality part of the somatic innervation to the



Text-fig. 2. Diagram showing a grey ramus of the cervical region containing somatic motor fibres in its distal part. The motor fibres from C3 join the grey ramus along *b* and leave it, to reach the muscle, along *c*. Part *a* is devoid of somatic fibres.

prevertebral muscles. It is of interest that they do not merely run alongside the fibres of the grey ramus, but in most instances the two become incorporated into the same nerve bundle.

The roots of the splanchnic nerves as they emerge from the sympathetic chain, both in the thoracic and in the upper lumbar region, have precisely the same appearance histologically as the white rami. This is to be expected since they are composed largely of preganglionic and afferent fibres.

SUMMARY

1. A study of the connexions of the human sympathetic chain in 25 dissections has revealed the commonest types of ganglia found at each segmental level. There was great complexity in the lumbar region and it was rarely possible to define an independent 'third' or 'fourth' lumbar ganglion. The different types of ganglia found respectively in the cervical, thoracic, lumbar and sacral regions reveal a fundamental pattern, indicative of a splitting and secondary fusion of each primordial ganglionic mass. Ganglia placed along the course of a ramus were surprisingly common especially in the lower lumbar region, and resulted of course from a greater degree of peripheral migration of cells than usually obtains.

2. A double sympathetic chain occurred anywhere along the sympathetic chain but never extended for more than the distance between two adjacent ganglia and probably therefore does not present any surgical problem. Transverse connexions between the sympathetic chains of each side were never found above the level of the fifth lumbar vertebra. The possibility of any bilateral innervation of the limbs via such transverse connexions can be almost certainly excluded.

3. Examples of rami connected with every spinal nerve have been studied histologically. The same four types of rami, according to fibre constitution, as described previously in the monkey, are present in man. In the thoracic region it was the rule for

the white (or mixed) ramus to be that which joins the spinal nerve most distally; in the lower thoracic and upper lumbar regions the 'transverse' rami were almost invariably grey, and the 'oblique' white.

4. The number of fine myelinated fibres (under 3μ in diameter) within grey rami has been greatly underestimated. They occurred in great numbers in the rami of C7 and C8 and again in those of L5 and S1, a distribution corresponding to that found in the cat and monkey.

5. The thoraco-lumbar outflow in man has been confirmed as T1–L2 (inclusive).

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EXPLANATION OF PLATES

PLATE 1

From a dissection of the sympathetic chain, rami communicantes and splanchnic nerves (adult human). The preganglionic rami are indicated in red. The postganglionic rami, the sympathetic chain and the splanchnic nerves are shown in black.

PLATE 2

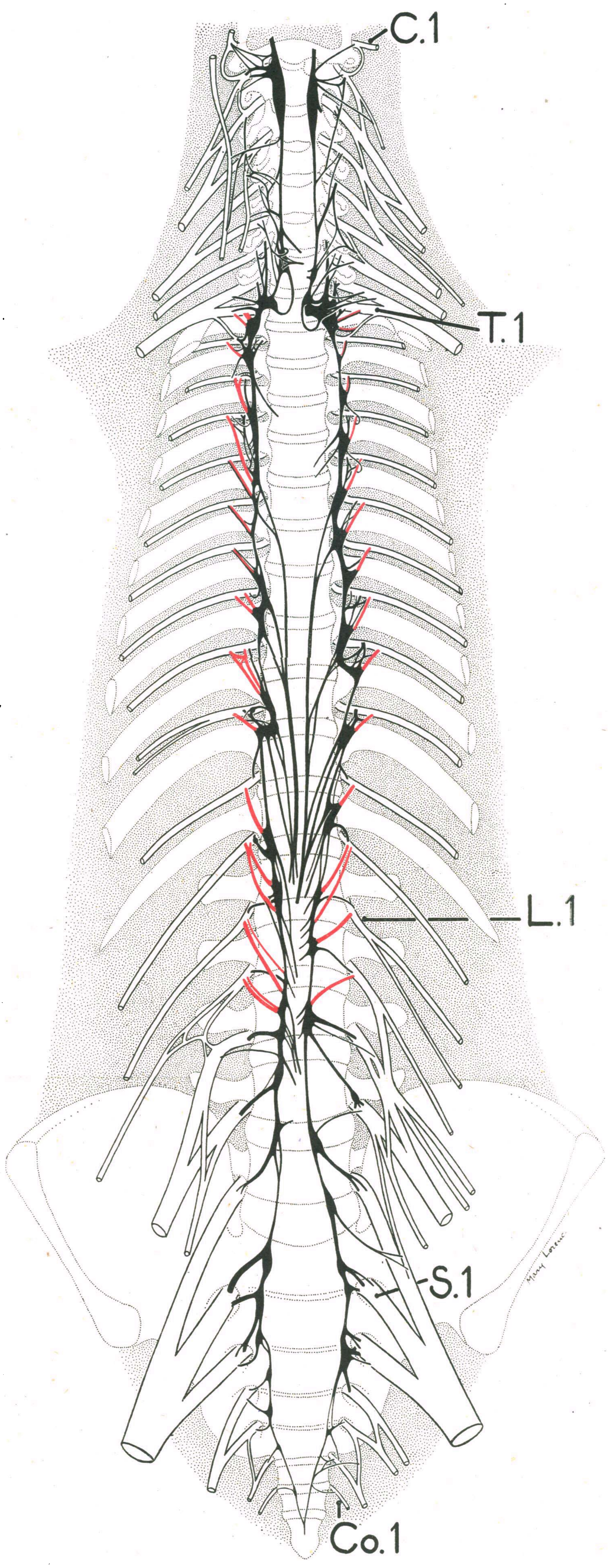
a. Section of a white ramus communicans representing 'Type I'. It contains myelinated fibres of all sizes. Stained with 1% osmic acid. Mag. ×185.

b. High-power view of the section shown in fig. *a*. Mag. ×556.

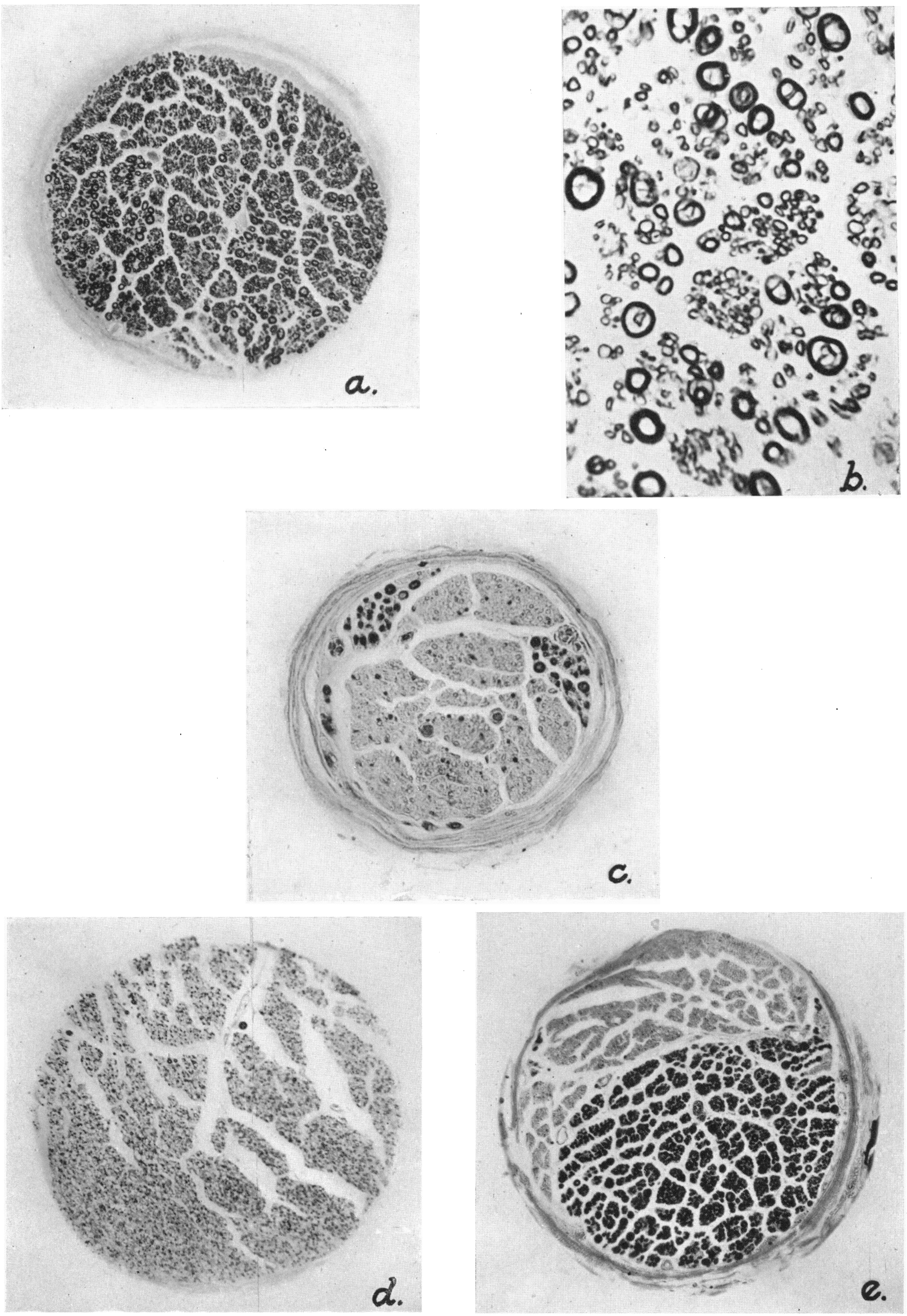
c. Section of a grey ramus communicans illustrating 'Type II A'. Note the two small areas occupied by large myelinated fibres. A few fine myelinated fibres are scattered throughout the unmyelinated portion of the nerve. Stained with 1% osmic acid. Mag. ×368.

d. Section of a grey ramus communicans illustrating 'Type II B'. The nerve is heavily 'peppered' with fine myelinated fibres. Stained with 1% osmic acid. Mag. ×185.

e. Section of a mixed ramus communicans of 'Type III'. The myelinated and unmyelinated portions are combined in one nerve bundle. Stained with 1% osmic acid. Mag. ×185.



PICK AND SHEEHAN—SYMPATHETIC RAMI IN MAN



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