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CENTRAL INNERVATION OF NEURONES IN THE INFERIOR MESENTERIC GANGLION AND OF THE LARGE INTESTINE OF THE CAT

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SUMMARY

1. Segmental, lumbar sympathetic outflow to neurones in the cat inferior mesenteric ganglion and to the large intestine were studied. Synaptic responses of neurones in the inferior mesenteric ganglion were recorded intracellularly, *in vitro*, during electrical stimulation of preganglionic fibres in the lumbar white rami. Synaptic responses consisted of excitatory post-synaptic potentials and/or action potentials.

2. None of the neurones tested received synaptic input from spinal cord segment L_1. There was synaptic input from segments L_2–L_5 of the spinal cord. The strongest synaptic input arose from spinal cord segments L_3 and L_4.

3. 42% of the neurones tested received synaptic input from only one spinal cord segment. 54% of the neurones tested received convergent synaptic input from two, three or four adjacent lumbar segments.

4. Electrophysiological measurements indicated that the number of preganglionic fibres in any lumbar white ramus communicans which provided synaptic input ranged from one to thirteen. Each lumbar white ramus contained, on average, five preganglionic fibres which provided synaptic input to neurones in the inferior mesenteric ganglion.

5. Changes in intraluminal colonic pressure were measured *in vivo* during electrical stimulation of preganglionic fibres in the different lumbar white rami and lumbar ventral roots. Electrical stimulation of white rami L_3 and L_4 abolished phasic changes in intraluminal colonic pressure and reduced basal pressure to near zero. Electrical stimulation of preganglionic fibres in lumbar ventral roots L_3 and L_4 abolished phasic changes in intraluminal colonic pressure and reduced basal pressure to near zero. Stimulation of ventral roots L_1, L_2 and L_5 had little to no effect on intraluminal pressure.

6. Based on the data obtained in this study, two hypotheses are proposed. First, spinal cord segments L_3, L_4 and L_5 are the primary sources of central synaptic input to neurones in the inferior mesenteric ganglion. Secondly, spinal cord segments L_3 and L_4 control colonic motility.

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INTRODUCTION

Lumbar sympathetic pathways which originate from preganglionic neurones in the spinal cord innervate noradrenergic neurones in the inferior mesenteric ganglion and thereby inhibit the external smooth muscle layers of the large intestine (Langley & Anderson, 1895; Garry, 1933; Weems & Szurszewski, 1977; de Groat & Krier, 1979). Precisely which segments of the lumbar spinal cord supply preganglionic fibres to the ganglion and which regulate motor activity of colonic smooth muscle are not known.

The present investigation was undertaken to determine whether neurones in the inferior mesenteric ganglion and the external smooth muscle layers of the large intestine receive an equal or unequal distribution of synaptic inputs from preganglionic neurones located in specific segments of the lumbar cord. The results suggest that the inhibitory outflow to both originates primarily in the third and fourth segments of the lumbar spinal cord.

Preliminary reports of these observations have been published previously (Krier & Szurszewski, 1980*a*, *b*).

METHODS

In vitro experiments. Experiments were performed on fourteen cats of either sex which were anaesthetized with chloralose (50–70 mg/kg, I.V.) after induction with ketamine (30 mg/kg, I.P.). Three cats were anaesthetized with dial urethane (allobarbitone, 100 mg/ml.; urethane, 400 mg/ml.; monoethylurea, 400 mg/ml.), (0·6 ml./kg, I.P.). Supplementary doses of chloralose (10 mg/kg, I.V.) or dial urethane (0·1 ml./kg, I.V.) were administered to maintain anaesthesia during the *in vivo* dissection procedures.

Following induction of anaesthesia, the inferior mesenteric ganglion and its neural connexions with the large intestine (lumbar colonic nerves, hypogastric nerves) and lumbar spinal cord (lumbar white rami communicantes, lumbar sympathetic chain, inferior splanchnic nerves) were exposed through a mid line abdominal incision. The left lumbar sympathetic chain and chain ganglia (L_2–L_6), and left lumbar white rami (L_1–L_5) were isolated and dissected free from the underlying connective tissue. Following these *in vivo* dissection procedures, the inferior mesenteric ganglion, its nerve trunks and the lumbar vertebral column (L_1–L_6) were removed from the animal and placed in a specially constructed organ bath. The bath was perfused with a modified Krebs solution containing (mM): Na^+, 137·4; K^+, 5·9; Ca^{2+}, 2·5; Mg^{2+}, 1·2, Cl^-, 134; HCO_3^-, 15·5; $H_2PO_4^-$, 1·2; glucose, 11·5, equilibrated with 97 % O_2 and 3 % CO_2 and warmed to 37–38 °C. The ganglion and attached nerve trunks were securely pinned to the floor of the bath.

The lumbar white rami L_1–L_4 and L_5 when present (Langley, 1896) were placed on bipolar, platinum wire electrodes. All nerve trunks were stimulated with rectangular pulses 0·5 msec in duration and at a constant frequency of 0·5 Hz. The intensity of stimulation depended upon the experiment. Maximum intensity was used to determine if a nerve trunk contained preganglionic axons which made synaptic contact with an impaled neurone, and graded intensities of stimulation were used to determine the number of preganglionic axons in a given nerve trunk. The distribution of preganglionic fibres arising from lumbar spinal segments L_1–L_5 to neurones of the inferior mesenteric ganglion was determined by recording synaptic responses intracellularly from neurones in the ganglion during electrical stimulation of the lumbar white rami. The methods used to record intracellularly from the ganglion cells have been described previously (Weems & Szurszewski, 1978). At the end of each experiment the lumbar spinal cord and lumbar roots (L_1–L_6) were exposed by laminectomy and each white ramus was traced from its lumbar sympathetic chain ganglia to its respective spinal cord segment. The preparation is illustrated diagrammatically in Fig. 1.

In vivo experiments. Experiments were performed on eight cats of either sex anaesthetized with dial urethane (0·6 ml./kg, I.P.). or chloralose (50–70 mg/kg, I.V.). Following the insertion of a tracheal cannula, the large intestine was exposed through a mid line abdominal incision. Colonic intraluminal pressure was measured by inserting a thin-walled rubber balloon into the colon (3 cm

above pelvic brim) through an incision made below the ileocaecal sphincter. The balloon, which was 3 cm in length, was connected by a catheter to a pressure transducer. After closing the colonic and abdominal incisions, a lumbosacral laminectomy was performed exposing the lumbar spinal cord and lumbar dorsal and ventral roots. Stimulating electrodes were positioned on the peripheral ends of the left ventral roots (L_1–L_6) for subsequent stimulation of the preganglionic fibres using

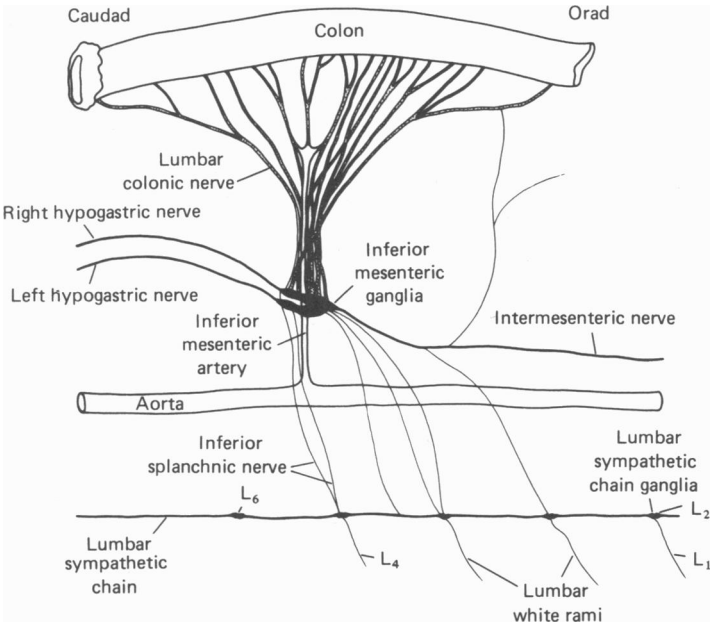

Fig. 1. Diagrammatic sketch of the lumbar sympathetic pathways to the inferior mesenteric ganglion and large intestine of the cat. See text for further details. Note white ramus communicans L_1 leads to the second sympathetic chain ganglion, communicans L_2 leads to the third ganglion, etc. This is consistent with Langley's (1896) original observations.

rectangular pulses of 0·05 msec duration at frequencies ranging from 2 to 20 Hz. The ventral roots were stimulated at intensities that produced maximum reduction of colonic intraluminal pressure. In each case the dorsal roots (L_1–L_6) were sectioned bilaterally.

In four additional cats, the stimulating electrodes were attached to white rami L_3 and L_4 which were later stimulated in precisely the same way as the ventral roots.

Arterial blood pressure was monitored by means of a catheter inserted into the left carotid artery and connected to a pressure transducer. In twelve cats, the mean arterial pressure ranged from 105 to 150 mmHg (mean 125). In each cat, the mean arterial pressure was maintained within narrow limits ($\pm$4 mmHg) for the duration of the experiment (5–7 hr).

Following all the above mentioned procedures, the animals were paralysed by the administration of gallamine triethiodide (4–5 mg/kg, I.V.) and artificially respired. The dose of dial urethane or chloralose was invariably sufficient to maintain surgical anaesthesia for the duration of each experiment. Our experience with non-paralysed preparations indicates that the dose of dial urethane or chloralose was sufficient to maintain surgical anaesthesia for the duration of the experiment (5–7 hr). The depth of anaesthesia, however, was checked at hourly intervals by discontinuing the continuous administration of galamine (4 mg/kg.hr) and assessing the depth of anaesthesia in the absence of the muscle relaxant. During the absence of the muscle relaxant, we tested for the presence of nociceptive reflexes by pinching the skin and muscle in the hind and

forelimbs. If nociceptive reflexes were present, we administered supplementary doses of chloralose (10 mg/kg, I.V.) or dial urethane (0·1 ml./kg, I.V.).

RESULTS

Anatomy. As originally described by Langley (1892), the inferior mesenteric ganglion of the cat consisted of four lobes, two usually above the inferior mesenteric artery and two usually below.

The ganglion is connected to the lumbar spinal cord via the lumbar white rami communicantes. Each lumbar segment of the spinal cord gave rise to a lumbar white

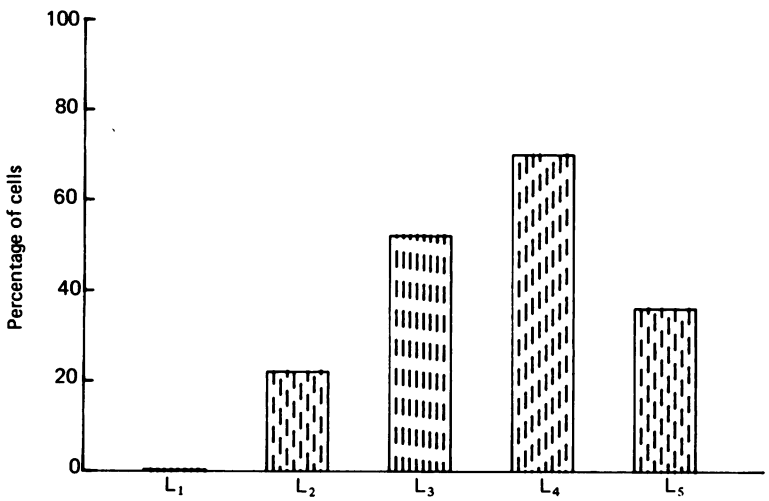

Fig. 2. Origin of central synaptic input to neurones in the inferior mesenteric ganglion. Height of columns represent percentage of cells tested which received input from the lumbar segment indicated. No neurones tested received input from L_1. The majority of neurones received input from white rami L_3 and L_4.

ramus. In the cat, each ramus connects with the corresponding ganglion (second to sixth) of the sympathetic chain (Fig. 1) (Langley, 1896). Fibres from the third to sixth lumbar sympathetic chain ganglia emerged to form the inferior splanchnic nerves.

Nerve fibres which connect the lobes of the ganglion with the large intestine and anal sphincters are part of the lumbar colonic and hypogastric nerves, respectively (de Groat & Krier, 1979; Garrett, Howard & Jones, 1974) (Fig. 1).

Electrophysiology

Intracellular recordings were obtained from 145 neurones in fourteen preparations. The intracellular resting membrane potential of neurones in normal Krebs solution ranged from -42 to -65 mV; the mean $\pm$S.E. of mean was $-52 \pm 2{\cdot}0$ mV. The input resistance ranged from 15·0 to 56·0 MΩ (46 ± 14 MΩ; $n = 15$). The threshold depolarization for initiation of a single action potential ranged from 5 to 18 mV. The voltage trajectory of an action potential was the same as that previously described for the inferior mesenteric ganglion of the guinea-pig (Weems & Szurszewski, 1978).

Central synaptic input from lumbar spinal segments. Axons of preganglionic neurones in a segment of the lumbar spinal cord have been shown to emerge solely via the ventral root and white ramus corresponding to that segment (Krier, Booth, Schauble & de Groat, 1978). In order to determine whether preganglionic axons in all lumbar segments made synaptic contact with neurones in the inferior mesenteric ganglion,

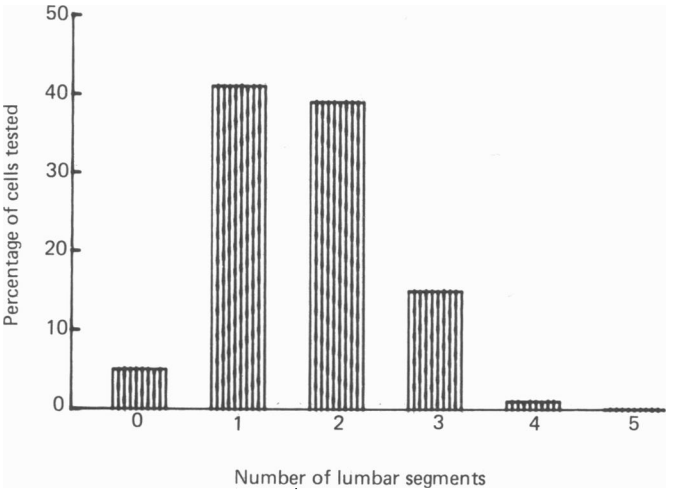

Fig. 3. Number of lumbar cord segments which provided synaptic input to neurones in the inferior mesenteric ganglion. Abscissa, number of spinal cord segments which provide synaptic input; ordinate, percentage of cells tested which received convergent input. Most neurones received input from one (42 %) or two (39 %) segments. Note 4 % of cells tested did not receive synaptic input from any lumbar cord segment.

we stimulated the white rami arising from spinal cord segments L_1–L_5 at maximum intensity. The data obtained are summarized in Fig. 2. No synaptic responses were elicited in neurones during electrical stimulation of the first lumbar white ramus (0 out of 33 neurones). In contrast, electrical stimulation of the second to fifth lumbar white rami at maximum intensities of stimulation elicited synaptic responses. 70 % (85 out of 122) of the neurones tested received input from L_4, 52 % (64 out of 123) received input from L_3, 36 % (22 out of 60) received input from L_5 and 22 % of the neurones tested (24 out of 118) received synaptic input from white ramus L_2. Thus, the principal source for synaptic input to neurones in the inferior mesenteric ganglion arose primarily from spinal cord segments L_3 and L_4.

Most neurones received synaptic input from one (42 %) or two (39 %) segments of the lumbar spinal cord. 15 % of neurones tested received multiple synaptic inputs from three or four spinal cord segments. 4 % of the neurones tested did not receive synaptic input from any lumbar spinal cord segment. These data are summarized in Fig. 3.

The majority of neurones in the inferior mesenteric ganglion which received multiple synaptic inputs from either two, three or four lumbar spinal cord segments received them from adjacent cord segments. The results are graphically illustrated

in Fig. 4. Data in panel *A* were obtained from cats in which a fifth lumbar white ramus was present, whereas the data in panel *B* were obtained from cats in which the fifth white ramus was absent. In both panels, the presence of a line indicates the lumbar segment which contributed synaptic input to a particular neurone. Thus, for example, a continuous line through L_2, L_3 and L_4 columns indicates that the neurone tested

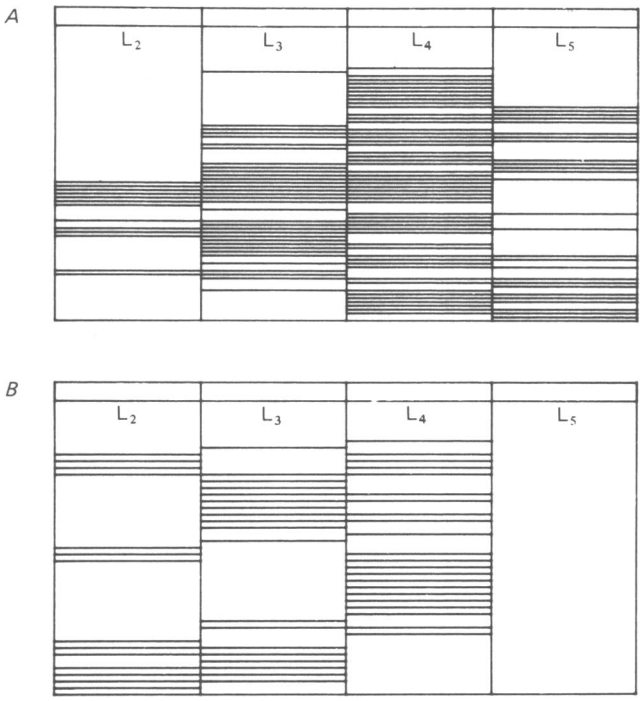

Fig. 4. Graphic illustration of origin of convergent central synaptic input to single neurones in the inferior mesenteric ganglion. Presence of a line indicates occurrence of synaptic input from the white ramus indicated. Panel *A*, data from cats with a fifth lumbar white ramus; panel *B*, data from cats without a fifth white ramus. 98 % of those neurones which received input from more than one lumbar segment received this multiple input from adjacent segments. See text for further details.

received synaptic input from each of these lumbar segments. Close inspection of Fig. 4 shows that neurones received synaptic input primarily from segments L_3 and L_4 and when input occurred from two adjacent segments, these were usually L_3 and L_4.

Synaptic responses. Synaptic responses which were elicited during maximum intensity of stimulation were subthreshold excitatory post-synaptic potentials (e.p.s.p.) and/or action potentials. Examples of these synaptic responses are shown in Fig. 5. Synaptic responses were elicited by electrical stimulation of the white ramus L_3. Each frame consists of six superimposed traces to aid identification of synaptically evoked responses. Subthreshold responses consisted of one (Fig. 5*A*) or several (usually two to five) e.p.s.p.s at different latencies (Fig. 5*C*) whereas threshold and above threshold responses consisted of either a single action potential or of various

combinations of action potentials (usually one or two) and e.p.s.p.s (usually one to four) at different latencies (Fig. 5*F*). When either white rami L_2 or L_5 were stimulated, 70 % of the neurones tested responded only with e.p.s.p.s. The remainder of the neurones responded with both e.p.s.p.s and action potentials. In contrast, 54 % of the neurones tested responded with both e.p.s.p.s and action potentials when either

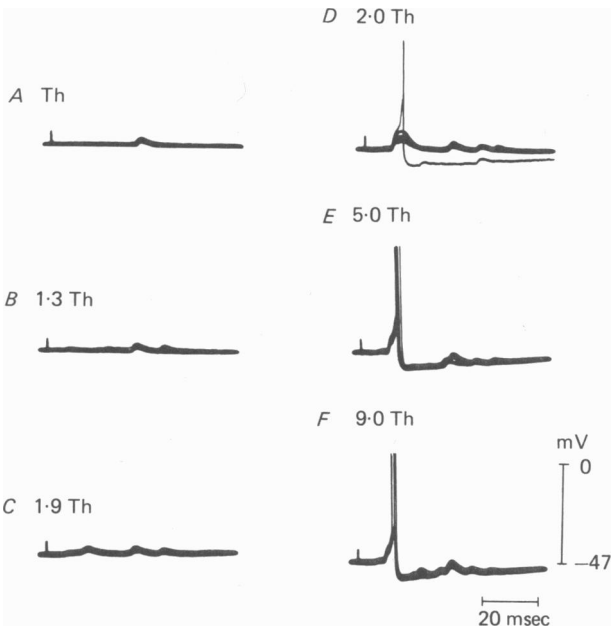

Fig. 5. Synaptic responses in a single neurone to stimulation of preganglionic axons in white ramus at six different intensities of stimulation. Each trace consists of six successive responses to nerve stimulation at the same intensity. Panel *A*, response to threshold (Th) stimulation; panel *F*, response to nine times threshold. Panels *B*–*E*, response to different intensities of stimulation expressed as multiples of the threshold (Th) response. Response in panel *F* represents maximum synaptic response.

L_3 or L_4 was stimulated. These data suggest that segments L_3 and L_4 provided a greater synaptic input than L_2 and L_5.

Estimation of the number of preganglionic fibres in each lumbar white ramus synapsing on neurones in the inferior mesenteric ganglion. In five preparations we estimated the number of preganglionic fibres in white rami L_2, L_3, L_4 and L_5 which provided synaptic input to neurones of the inferior mesenteric ganglion. This was accomplished by recording intracellularly and increasing the stimulus intensity until a synaptic response was just detected. Once an e.p.s.p. was elicited, increases in the strength of stimulation increased the amplitude of the e.p.s.p. either to a maximal subthreshold level or to threshold level for initiation of a single action potential. Further increases in stimulus intensity resulted in additional synaptic potentials which occurred at different latencies (Fig. 5). Synaptic responses of different latencies for a neurone in the inferior mesenteric ganglion during electrical stimulation of white ramus L_3 at

different intensities of stimulation are shown in Fig. 5. Increasing intensities of nerve stimulation are expressed as multiples of threshold for initiation of the 30 msec e.p.s.p. shown in panel *A*. Increasing intensities of stimulation elicited additional synaptic responses at longer and shorter latencies (Panels *B–F*). The maximum number of responses which occurred at nine times threshold (panel *F*) was nine. Occurrence of additional multiple synaptic responses have been shown to be due to recruitment of additional preganglionic fibres (Crowcroft & Szurszewski, 1971). Thus, there were nine preganglionic fibres in white ramus L_3 which synapsed on the neurone tested. In nine other neurones, the estimated number of preganglionic fibres emanating from any single lumbar white ramus ranged from 1 to 13. The mean number ($\pm$S.E. of mean) was $5 \pm 0{\cdot}6$. The estimated number of preganglionic fibres in each white ramus tested (L_2–L_5) was not significantly different from each other.

Conduction velocities of preganglionic fibres in the lumbar white rami. Neurones in the inferior mesenteric ganglion receive a segmental innervation from the L_2 to L_5 segments of the lumbar spinal cord. In this series of experiments, we wanted to determine whether neurones in the inferior mesenteric ganglion received a selective pattern of innervation based upon conduction velocities of preganglionic fibes located in different lumbar white rami. Conduction velocities were calculated by measuring the latencies (range 5–100 msec, mean 60 ± 15 S.E. of mean) of synaptic responses evoked in neurones during electrical stimulation of preganglionic axons, subtracting 9·3 msec (the time for synaptic delay measured for neurones in the coeliac (Kreulen & Szurszewski, 1979) and inferior mesenteric ganglia (J. H. Szurszewski, unpublished observations)) and dividing by the conduction distance measured in centimetres. Estimates were made from responses recorded in seventeen neurones and in each case the conduction distance was measured from the cathode of the stimulating electrode to the position of the recording micro-electrode. The distribution of calculated conduction velocities of preganglionic fibres in the lumbar white rami which provided synaptic input to neurones in the ganglion is shown in Fig. 6. 68% of the preganglionic fibres were estimated to conduct at velocities ranging from 0·5 to 2 m/sec, and the rest ranged from 2 to 6·8 m/sec. These data suggest that both B and C fibres innervate neurones in the inferior mesenteric ganglion of the cat.

Neurones in this ganglion received convergent synaptic input from both B and C preganglionic fibres located in either the same or different lumbar white rami. An example of a neurone receiving a synaptic input from both B and C fibres, located in different rami, is shown in Fig. 7. Panel *A* shows a synaptically evoked action potential resulting from electrical stimulation of preganglionic fibres in white ramus L_2. The calculated conduction velocity was 1·9 m/sec. Panel *B* shows excitatory post-synaptic potentials and an action potential resulting from electrical stimulation of preganglionic fibres in white ramus L_4. The calculated conduction velocity of the preganglionic fibre which gave rise to these latter synaptic responses was 6·8 m/sec. These data suggest that there was no selective pattern of neuronal innervation based upon the conduction velocities of preganglionic fibres in lumbar white rami.

Lumbar sympathetic inhibitory outflow to the large intestine. Some of the autonomic preganglionic fibres which originate in the lumbar spinal cord synapse on noradrenergic neurones which innervate the motor apparatus of the large intestine. Release of noradrenaline reduces or inhibits spontaneous contractions. The *in vitro*, electro-

physiological data described above suggest that the third and fourth segments of the lumbar cord provide the principal synaptic input to noradrenergic neurones in the inferior mesenteric ganglion. It would seem, therefore, that the third and fourth segments of the lumbar cord should have greater influence on colonic motility than the first, second and fifth.

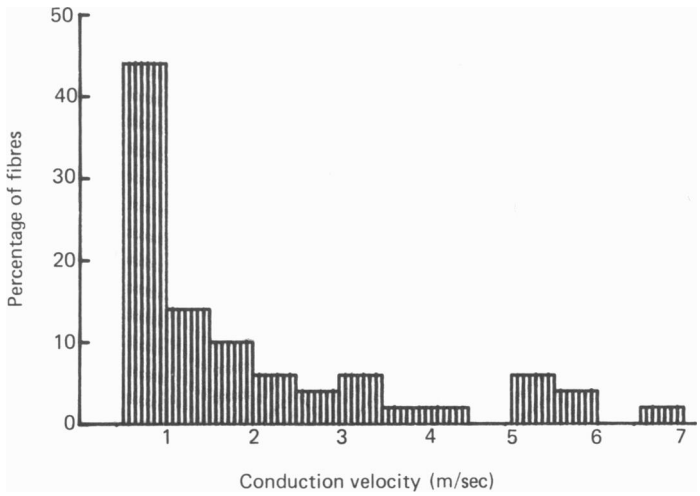

Fig. 6. Distribution of calculated conduction velocities of lumbar preganglionic fibres synapsing on neurones in inferior mesenteric ganglion. See text for further details.

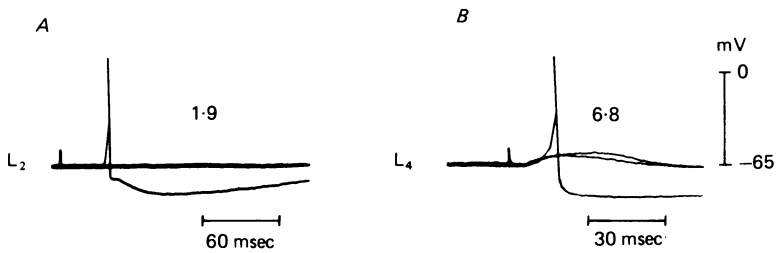

Fig. 7. Synaptic response in a neurone following electrical stimulation of a preganglionic fibre in L_2 (left) and L_4 (right) white rami. Calculated conduction velocity of fibre in L_2 white ramus was 1·9 m/sec; in L_4, 6·8 m/sec. Each trace consists of three successive threshold responses to nerve stimulation of constant strength.

This hypothesis was tested in two series of experiments performed *in vivo*. In the first series, we examined the effect of electrical stimulation of white rami L_3 and L_4 on intraluminal pressure of the distal colon in four cats. The same intensity (10 V), duration (0·05 msec) and frequency (10 Hz) of stimulation was employed in each case. In all four experiments stimulation inhibited phasic changes in intraluminal pressure and reduced to basal intraluminal pressure to $\leqslant 0$ cm H_2O. These results suggest that two of the white rami which provide the synaptic input to neurones in the inferior mesenteric ganglion are also involved in the control of colonic motility.

In the second series of experiments, the effect of electrical stimulation of the lumbar

ventral roots (L_1–L_5) on intraluminal pressure of the distal colon were examined *in vivo* in eight cats. In these experiments, all the lumbar dorsal roots were sectioned. The same stimulus as that described above was employed to test each ventral root in turn. An example of the results obtained in one of these experiments is shown in Fig. 8. In this Figure, the letter and number to the left of each trace indicate the lumbar

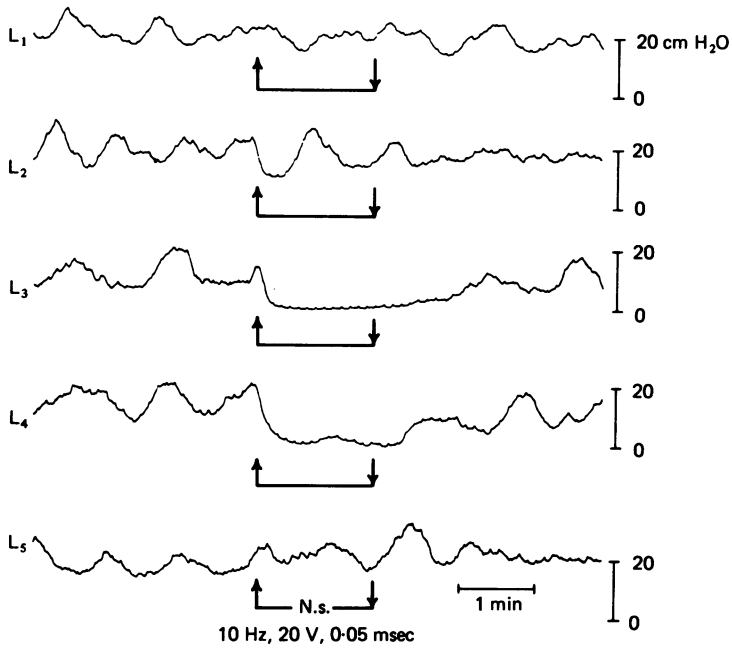

Fig. 8. Effect of stimulation of ventral roots L_1–L_5 on intraluminal pressure recorded *in vivo* from the colon. Abscissa, time in minutes; ordinate, colonic pressure in cm water. Arrows and bars below each trace indicate period of nerve stimulation (N.s.). See text for further details.

ventral root stimulated. The duration of stimulation of each lumbar ventral root is indicated by the bar and arrows. Electrical stimulation of ventral roots L_3 and L_4 inhibited phasic changes in intraluminal pressure and reduced basal tone to $\leqslant 0$ cm H_2O. Stimulation of ventral root L_2 may have transiently reduced phasic contractions initially but stimulation of L_1 and L_5 had no discernible effect on intraluminal pressure.

In each of these eight experiments, stimulation of either ventral root L_1 or L_5 failed to alter intraluminal pressure. In seven experiments inhibition of intraluminal pressure occurred only during electrical stimulation of ventral roots L_3 and L_4. In the single exception (Fig. 8), reduction of intraluminal pressure may have occurred during stimulation of L_2 ventral root. The inhibitory responses of the colonic musculature during electrical stimulation of ventral roots L_3 and L_4 were invariably abolished after sectioning the lumbar spinal nerves. Since the lumbar dorsal roots were also sectioned, the effect of sectioning the spinal nerves indicates that the inhibitory effects were mediated by preganglionic fibres which arose from neurones

located in the lumbar spinal cord. These *in vivo* data suggest that segments L_3 and L_4 of the lumbar spinal cord play a major role in the central nervous control of colonic motor activity. The same segments of the lumbar cord (L_3 and L_4) provided most of the synaptic input to neurones in the inferior mesenteric ganglion in the *in vitro* experiments.

DISCUSSION

The data obtained in this study indicate that neurones in the inferior mesenteric ganglion received convergent synaptic input from central, preganglionic fibres. The number of preganglionic fibres in the lumbar white rami converging on a neurone depended upon the central pattern of innervation of which there were two types. In one, 42 % of neurones in the inferior mesenteric ganglion received convergent synaptic input from preganglionic fibres arising from a single segment of the lumbar spinal cord; the segments involved being either L_2, L_3, L_4 or L_5. The mean number of preganglionic fibres in each ramus which converged on this population of neurones was estimated to be five. In the second pattern, 58 % of neurones received convergent synaptic input from preganglionic fibres arising from two, three or four adjacent segments of the lumbar spinal cord. The majority of these neurones usually received synaptic input from two of the four segments of the lumbar spinal cord that contributed to the central innervation of the ganglion. Since the mean number of preganglionic fibres in a lumbar white ramus which innervated neurones in the ganglion was estimated at five and since each neurone in this population received, on the average, synaptic input from two lumbar white rami, the mean number of preganglionic fibres from the spinal cord converging on this population of neurones was estimated at ten.

The convergent pattern of central preganglionic innervation of neurones in the inferior mesenteric ganglion is similar to the central pattern of innervation of neurones in other prevertebral, autonomic ganglia. Neurones in the superior cervical and stellate ganglia of the guinea-pig receive synaptic input from an average of four of the eight thoracic segments that contribute to the central innervation of the ganglion. In the superior cervical ganglion the mean number of preganglionic fibres converging onto a neurone is ten (Nja & Purvis, 1977; Lichtman, Purvis & Yip, 1980). In the superior cervical ganglion of rabbits, an average of seven preganglionic fibres converged onto each neurone (Wallis & North, 1978).

Preganglionic fibres in the lumbar white rami which provided synaptic input to neurones in the inferior mesenteric ganglion had conduction velocities ranging from 0·5 to 7·0 msec. Thus, lumbar sympathetic pathways to the inferior mesenteric ganglion are composed of both B and C fibres. Preganglionic B and C fibres have also been identified at other sites within (or in) the autonomic nervous system. Synaptic input from B and C fibres onto two distinct populations of paravertebral sympathetic neurones has been reported in amphibians (Weight & Votava, 1970). In the sacral parasympathetic pathway to the large intestine and urinary bladder, preganglionic C fibres provide the major synaptic input to extramural colonic ganglia and to the large intestine, whereas preganglionic B fibres provide the major synaptic input to vesicular ganglia and to the urinary bladder (de Groat & Krier, 1976). In

the rabbit and guinea-pig superior cervical ganglion, some neurones receive convergent input from both B and C fibres (Erulkar & Woodward, 1968; Mirgorodsky & Skok, 1970; Perri, Sacchi & Casella, 1970). Thus, neurones in this ganglion, as in the inferior mesenteric ganglion of the cat, receive convergent presynaptic input from both B and C fibres.

The data obtained in this study suggest that central control of colonic motility in the cat depends mainly on the outflow from the third and fourth lumbar segments of the spinal cord. There are three lines of evidence which support this hypothesis. First, although neurones in the inferior mesenteric ganglion responded with excitatory post-synaptic potentials or action potentials or both during electrical stimulation of the second to fifth lumbar white rami, the maximal synaptic response was usually elicited during stimulation of the third and fourth white rami. Secondly, electrical stimulation *in vivo* of white rami L_3 and L_4 abolished phasic changes in intraluminal colonic pressure and reduced basal pressure. Thirdly, in the majority of preparations, inhibition of colonic intraluminal pressure was observed, *in vivo*, during electrical stimulation of the third and fourth lumbar ventral roots. No alteration in colonic intraluminal pressure was observed during stimulation of the first and fifth lumbar ventral roots. Thus, it seems likely that many of the neurones in the inferior mesenteric ganglion which receive input from the third and fourth lumbar spinal segments send their axons to the motor apparatus of the large intestine to inhibit colonic motility. It seems reasonable to conclude that central control of colonic motility occurs primarily via the third and fourth segments of the lumbar spinal cord.

Specificity of central segmental innervation is not limited to the lumbar preganglionic axons which convey synaptic inputs to the external smooth muscle layers of the colon, urinary bladder and sexual organs (Langley & Anderson, 1895; de Groat & Krier, 1979). Central vasomotor inputs to various vascular beds also seem to have a segmental arrangement. In the skeletal vasculature of the hind limb, maximal vasoconstrictor responses were observed during electrical stimulation of ventral roots L_1–L_3 whereas the maximal dilator responses were observed during stimulation of ventral root L_4 (Sonnenschein & Weissman, 1978). In the coeliac and superior mesenteric vascular beds, predominantly vasoconstrictor responses were observed during stimulation of the fourth to eighth thoracic ventral roots and the tenth to thirteenth thoracic ventral roots respectively (Brooksby & Donald, 1970). In addition, central vasomotor inputs to organs which are innervated by post-ganglionic fibres arising from the superior cervical ganglion originate from specific segments of the thoracic spinal cord (Langley, 1892, 1895; Nja & Purvis, 1977).

Finally, although the second and fifth white rami provided synaptic input to neurones in the inferior mesenteric ganglion, these same lumbar segments generally did not affect colonic motility when their ventral roots were electrically activated *in vivo*. The target structure for these two pathways is not known. It is possible that many of the neurones in the inferior mesenteric ganglion innervated via the second and fifth lumbar white rami send their axons to the pelvic plexus to innervate the urinary bladder, sexual organs or anal sphincters (Langley & Anderson, 1895; de Groat & Krier, 1979). It is possible that these neurones may innervate the colon and mediate functions other than intestinal motor inhibition as for example vasomotor

tone, intestinal absorption or secretion. It is equally possible that many of the neurones in the inferior mesenteric ganglion innervated by white rami L_3 and L_4 may also supply these structures.

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