J. Anat. (1983), **136**, 1, pp. 97–109
With 9 figures
Printed in Great Britain

Innervation of the gall bladder and biliary pathways in the guinea-pig*

WEN-QIN CAI† AND GIORGIO GABELLA

Department of Anatomy and Embryology, University College London, Gower Street, London WC1E 6BT

(*Accepted* 22 *March* 1982)

INTRODUCTION

Several authors have carried out neurohistological studies of the gall bladder and biliary pathways in mammals, using silver impregnation and methylene blue techniques (reviewed in Baumgarten & Lange, 1969; Solovieva, 1980). More recently, further studies have been published based on histochemical techniques for cholinergic and adrenergic nerves (Sutherland, 1966; Grapulin, Ottolenghi, Fagiolo & Vecellio, 1968; Sisto & Robecchi, 1968; Baumgarten & Lange, 1969; Mori, Azuma & Fujiwara, 1971; Tansy, Innes, Martin & Kendall, 1974; Kyösola, 1974, 1976, 1977, 1978; Kyösola & Rechardt, 1973; Kyösola & Penttila, 1977; Wahlin, Axelson, Schiebler & Winckler, 1977; Davison, Al-Hassani, Crowe & Burnstock, 1978; Onda & Miyazaki, 1980). The results presented by different authors are somewhat contradictory. For instance, in the dog, Grapulin *et al.* (1968) observed a rich supply of adrenergic nerves to different layers of the biliary duct, including the region of the papilla, whereas Tansy *et al.* (1974) failed to demonstrate histochemically an adrenergic nerve supply to this region (reviewed by Kyösola, 1975). Baumgarten & Lange (1969) demonstrated extrinsic adrenergic innervation of the smooth musculature in the extrahepatic biliary duct system in the cat and the rhesus monkey but not in the guinea-pig. However, Mori *et al.* (1971) found a rich plexus of adrenergic fibres in the musculature of the gall bladder and the choledochoduodenal junction in the guinea-pig and rabbit.

Therefore, a more detailed study of the innervation of the gall bladder and biliary pathways seemed desirable. The present study deals with the distribution of the nerve plexus studied – to some extent quantitatively – on whole mount stretch preparations and on sections of plastic-embedded specimens.

MATERIALS AND METHODS

Forty adult guinea-pigs of either sex were used. The animals were killed with an overdose of ether or by stunning and exsanguination. The gall bladder was removed intact, together with the cystic duct, the hepatic duct, the common bile duct and the cranial portion of the duodenum, and placed in Kreb's solution. Various portions were then separated. The gall bladder was emptied of its contents and then injected with 1–3 ml of Kreb's solution. The neck was tied to maintain a moderate distension.

* Reprint requests to Dr Gabella.
† Dr Cai is on leave from the Department of Anatomy and Embryology, Medical School, Chang-Hai Hospital, Shanghai, The People's Republic of China.

Primary fixation was carried out with 5% glutaraldehyde in 0·1 M Na cacodylate buffer at pH 7·4 for 2 hours at room temperature. Post-fixation was in 2% buffered osmic acid for 1 hour. Block-staining in 1% aqueous uranyl acetate for 30–60 minutes was followed by dehydration in ethanol and treatment with propylene oxide, after which the specimens were infiltrated with Araldite. Sections (2–3 μm thick) were cut with glass knives using a Porter Blum ultramicrotome and were stained with 1% toluidine blue or were examined unstained in a Zeiss phase contrast microscope.

For the quantitative work (ten guinea-pigs), sections which were transverse to the long axis of the organ examined were used. On drawings made by projecting a slide at $\times 125$, in a Reichert Visopan projectoscope, the linear extent of the musculature was calculated, taken as the average between the internal and external outlines of the muscle coat measured with an opisometer. The amount of nerve plexus, defined as the linear extent of the ganglia and meshes over a circumferential line parallel to the muscular surface, was measured with an eyepiece graticule previously calibrated on a micrometer slide. The ratio between the linear extent of the plexus and that of the muscle coat, or P/M (linear) ratio, was then calculated.

For the histochemical demonstration of catecholamines by fluorescence microscopy, the glyoxylic acid method described by Lindvall & Björklund (1974) was used, either on whole mount stretch preparations or on sections. To obtain whole mount preparations (ten guinea-pigs), the gall bladder and bile duct were slit open with microscissors and stretched on a glass slide. When the edge of the serous membrane had adhered to the glass, the layers of the wall were removed in sequence under a dissecting microscope. For sections (five guinea-pigs), the specimens were frozen in isopentane cooled with liquid nitrogen, freeze-dried and vacuum-embedded in Araldite. Sections of 2–3 μm were cut on a Porter Blum microtome and were collected on slides smeared with liquid paraffin. Coverslips were compressed with a small weight for a few minutes and ringed with D.P.X. Stretch preparations and sections were viewed in a Zeiss fluorescence photomicroscope, equipped with a 3RS epi-illumination system. For demonstration of AChE (acetylcholinesterase), the 'direct colouring' method introduced by Karnovsky & Roots (1964) was used. Fresh tissues were prepared as whole mount stretch preparations (twelve guinea-pigs) and as cryostat sections (three guinea-pigs).

RESULTS

Ganglionated plexus

The main component of the innervation of the gall bladder and the biliary pathways was a ganglionated plexus. Its ganglia and connecting strands formed a mesh which spread without interruption from the gall bladder to the cystic duct and then to the biliary duct, and was connected to the intramural plexus of the duodenum. In spite of this continuity, however, sizes and numbers of ganglia varied markedly in different regions (Table 1). In the gall bladder, the neck had a relatively larger supply of neurons, and of nervous tissue in general, than the fundus. The common bile duct was more richly innervated than the other ducts or the gall bladder, with the highest values for neuronal density in its lowermost part. An abundant nerve supply was also found in the sphincter of the papilla.

In the gall bladder, the plexus was mainly located in the serosa at the outer surface of the muscle coat (Fig. 1). Sometimes the ganglia were situated between muscle

Table 1. *Number of neurons and extent of the ganglionated plexus*

	Gall bladder			Cystic duct	Hepatic duct	Common bile duct			Papilla
	Fundus	Body	Neck			Upper	Middle	Lower	
A	6·5	5·6	3·6	3·3	1·1	2·9	12·6	42·1	8
B	0·21	0·24	0·9	0·7	0·4	0·8	2·0	0·7 7·3	17
C	0·13	0·18	0·02	0·04	0·03	0·03	0·44	0·77	0·026
D	3·5	7·0	1·1	1·1	0·8	1·3	1·3	1·3	0·055

(A) Average number of ganglion neurons counted on a single transverse section of the organ.
(B) Plexus to muscle ratio (P:M surface ratio) $\times 10^{-2}$; see methods. In the case of the lower common bile duct, the upper figure corresponds to the deep ganglionated plexus, the lower figure to the intramuscular plexus.
(C) Area of the muscle coat in transverse sections of the organ, in mm^2.
(D) Outer diameter of the organ, in mm.

bundles, particularly in the sites where the muscle layer was attenuated or discontinuous.

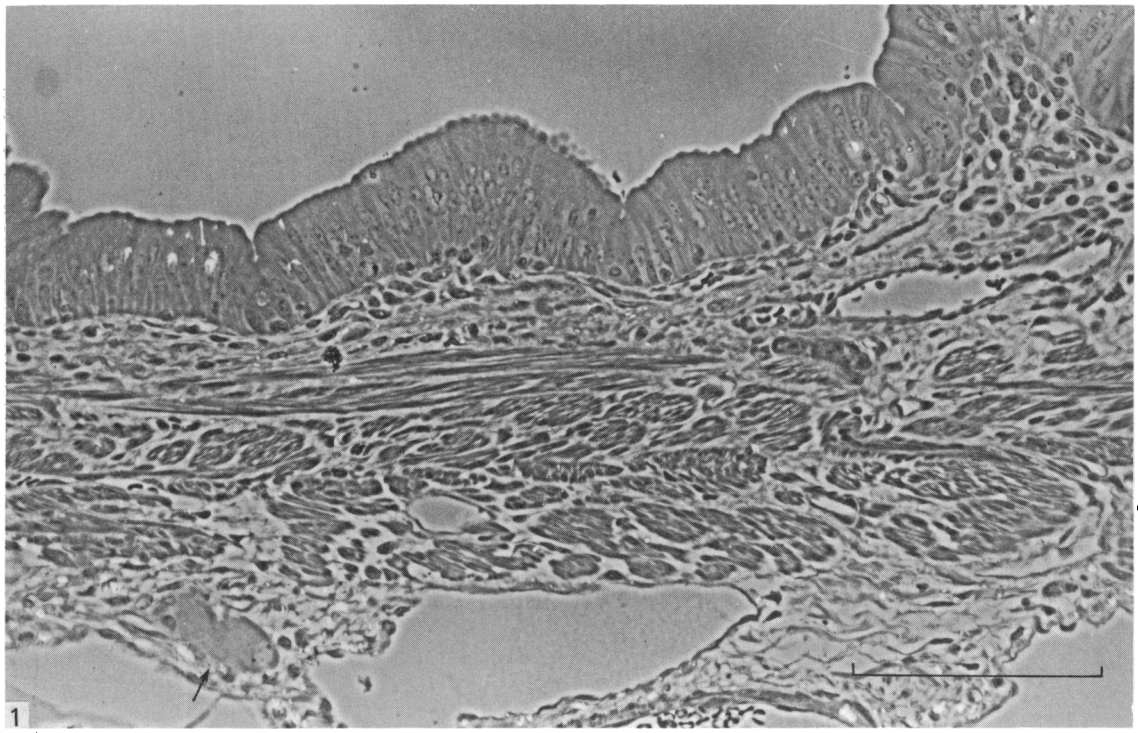
The plexus could be seen *in toto* in stretch preparations histochemically stained for acetylcholinesterase (Fig. 2). Most of the ganglia contained up to 4 neurons, but ganglia with up to 27 neurons were found. In addition, there were many single neurons lying along the connecting strands. The total number of neurons in the gall bladder was, on average, 367 (ranging from 314 to 428, five specimens). Some ganglia occupied the intersections of polygonal meshes and had a characteristic triangular outline; others lay along a nerve strand, producing a fusiform expansion or making a bulging mass connected to the nerve by a peduncle (Fig. 4). Some parts of the plexus lay close and parallel to the main arterial tree of the gall bladder.

The pattern of the ganglionated plexus in the gall bladder was distinctly different from that of the myenteric plexus in the small intestine, in that the ganglia were much fewer and smaller, and the connecting strands longer. There was, however, a certain similarity with the submucosal plexus, as regards size and shape of the ganglia and the angular pattern of the meshes (Fig. 3*a*, *b*).

The ganglionated plexus of the gall bladder extended into the cystic duct, the hepatic duct and the upper part of the common bile duct. Ganglia and meshes were situated in the subserosal membrane or sometimes between loosely arranged muscle bundles. From the middle portion of the bile duct downwards this plexus was positioned among the innermost muscle bundles or at the inner aspect of the circular muscle layer. Another plexus became apparent at this level, situated well within the muscle coat, usually between circular and longitudinal layers or between bundles of the outer longitudinal musculature. The latter plexus was in continuity with the myenteric plexus of the duodenum, while the other ganglionated plexus mentioned above extended into the duodenal submucosa and was connected to the submucosal plexus there. The two ganglionated plexuses of the lower part of the bile duct were also amply connected to each other. The overall distribution of nerve ganglia in the biliary system and the duodenum is schematically shown in Figure 9.

Acetylcholinesterase-positive nerves

The histochemical reaction for acetylcholinesterase was used primarily to stain the ganglionated plexus *in toto* and to identify other nerves and plexuses.



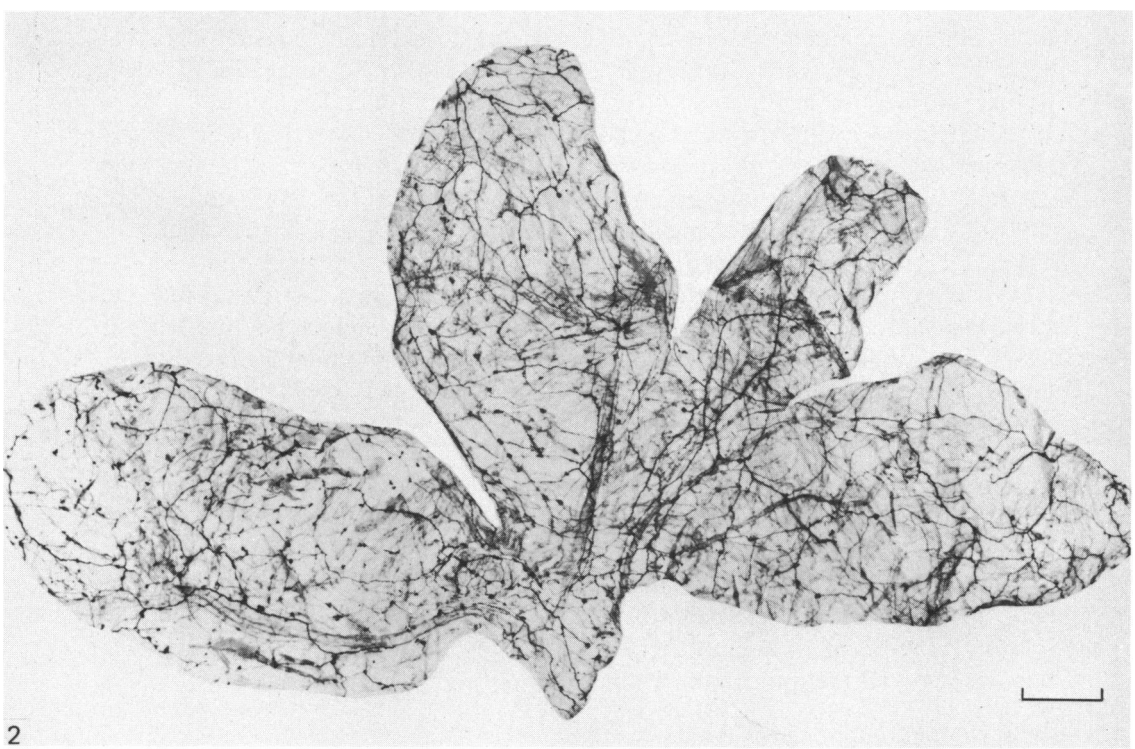


Fig. 1. Transverse section of the gall bladder, showing a nerve ganglion (arrow) situated in the serosa. Plastic embedded tissue, photographed unstained in phase contrast. Calibration bar: 100 μm.

Fig. 2. Whole mount stretch preparation of gall bladder, histochemically stained for acetylcholinesterase. Connecting strands are visible over a virtually unstained musculature. Calibration bar: 2 mm.

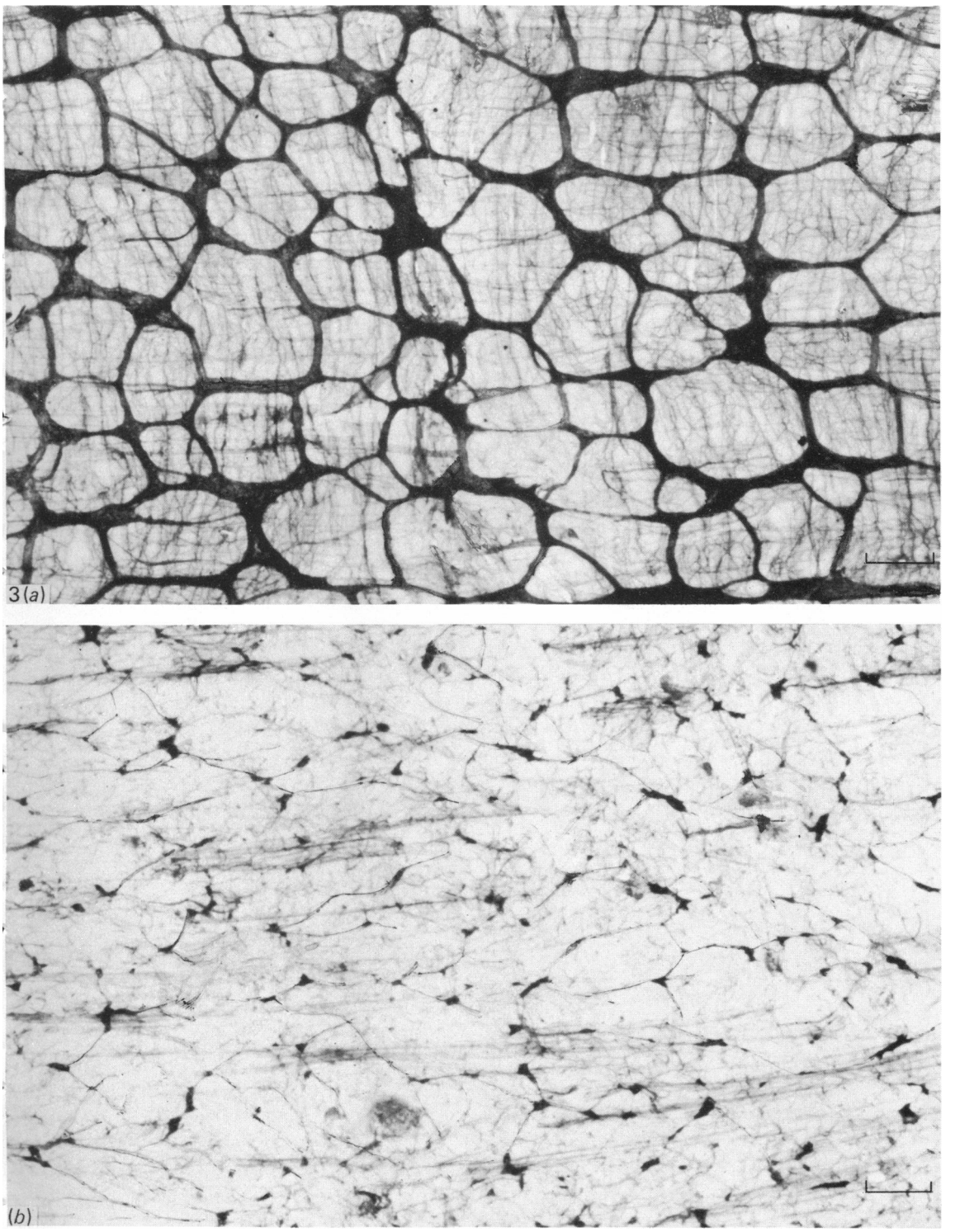
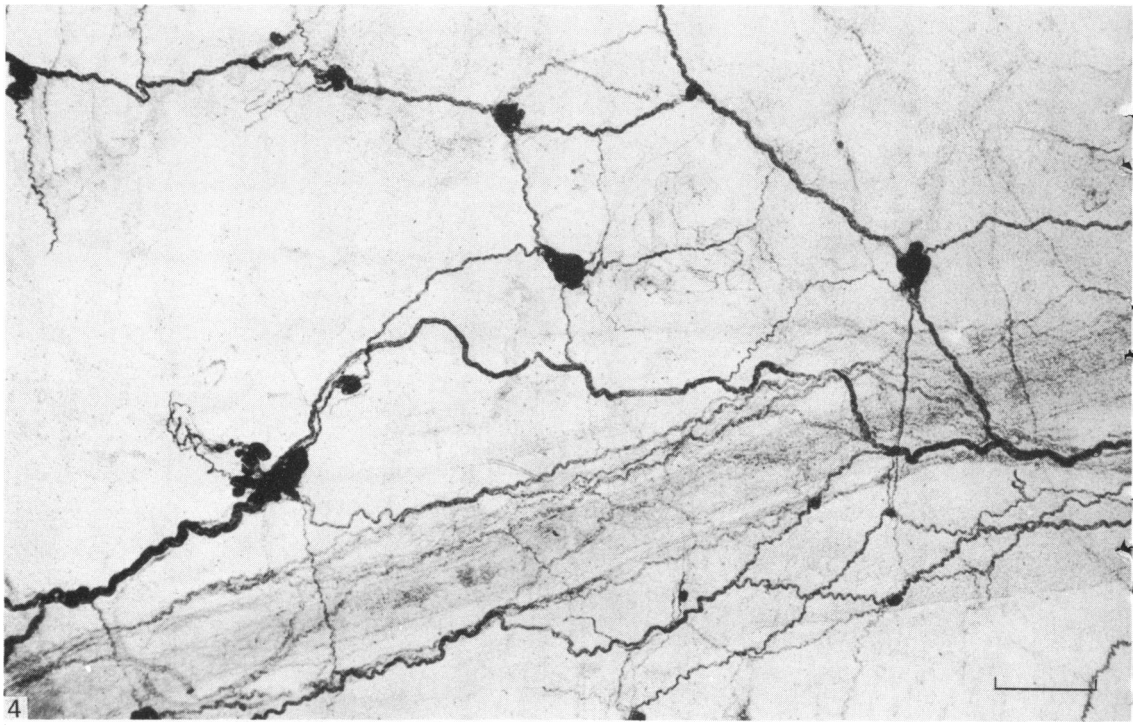


Fig. 3(*a–b*). Whole mount stretch preparations of the nerve plexuses of the duodenum, stained for acetylcholinesterase. (*a*) Myenteric plexus. (*b*) Submucosal plexus. Note some similarity between this plexus and the ganglionated plexus of the gall bladder (cf. Fig. 2), as regards shape, arrangement of the ganglia and the angular pattern of the meshes. Calibration bar: 400 μm.



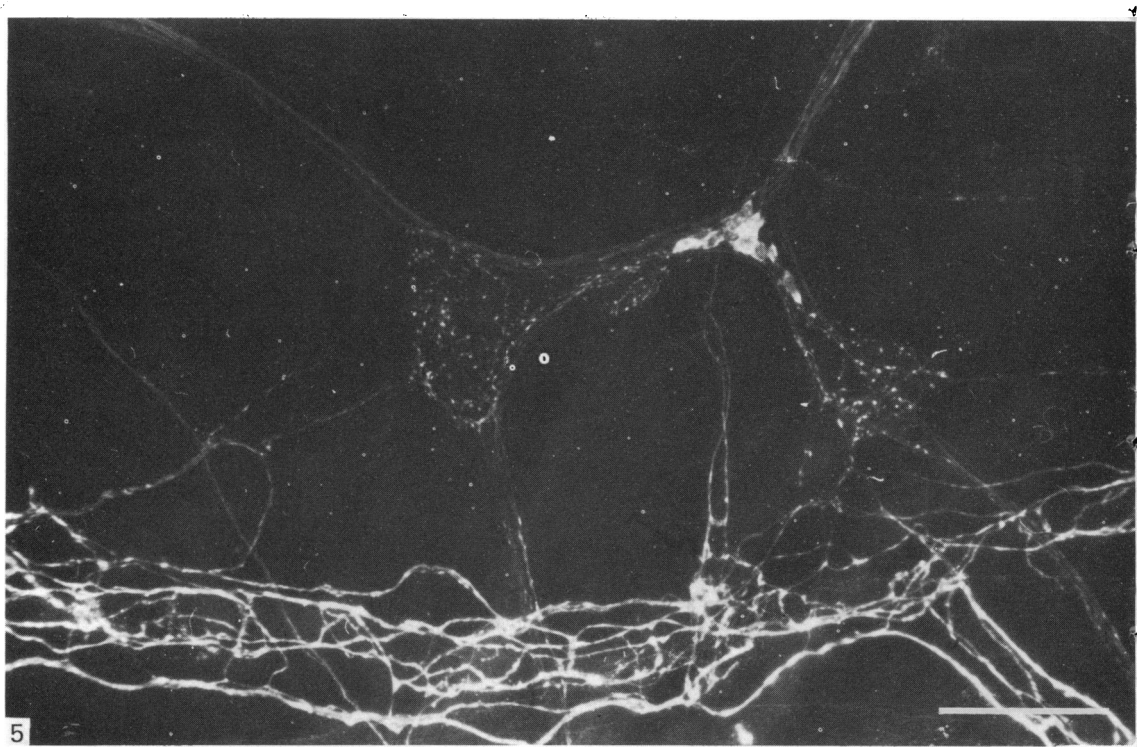


Fig. 4. Whole mount stretch preparation, stained for acetylcholinesterase, showing the ganglionated plexus of the gall bladder. Note the variation in size and shape of the ganglia and the closeness of some of its strands to the blood vessel. Calibration bar: 100 μm.

Fig. 5. Whole mount stretch preparation of the ganglionated plexus of the gall bladder, showing fluorescent varicose fibres in two ganglia. The dark areas within the ganglia are cell bodies of ganglion neurons, which are non-fluorescent. Along a connecting strand is a cluster of small intensely fluorescent cells. At the bottom a blood vessel displays a thick adventitial plexus of fluorescent nerves. Glyoxylic acid fluorescence. Calibration bar: 100 μm.

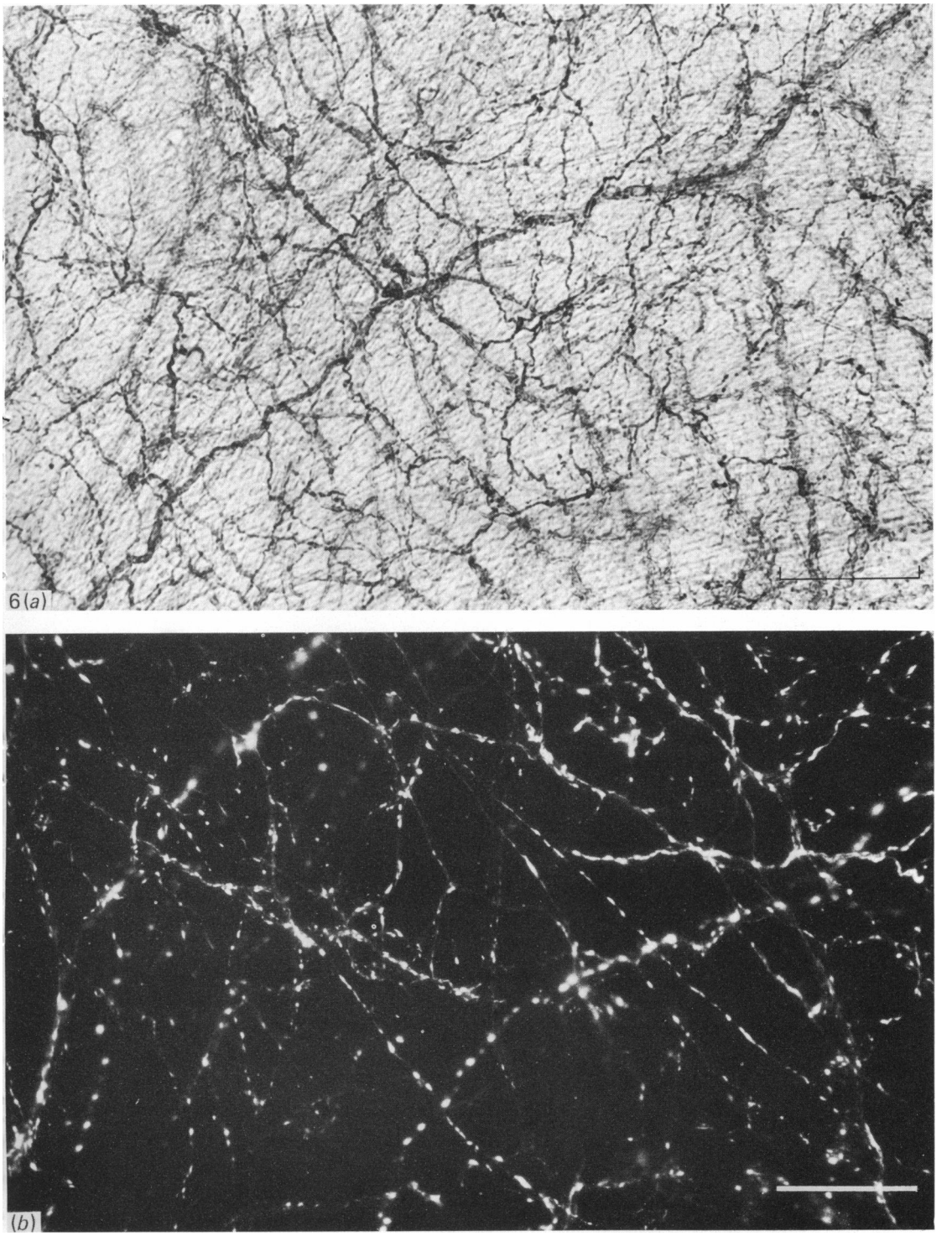
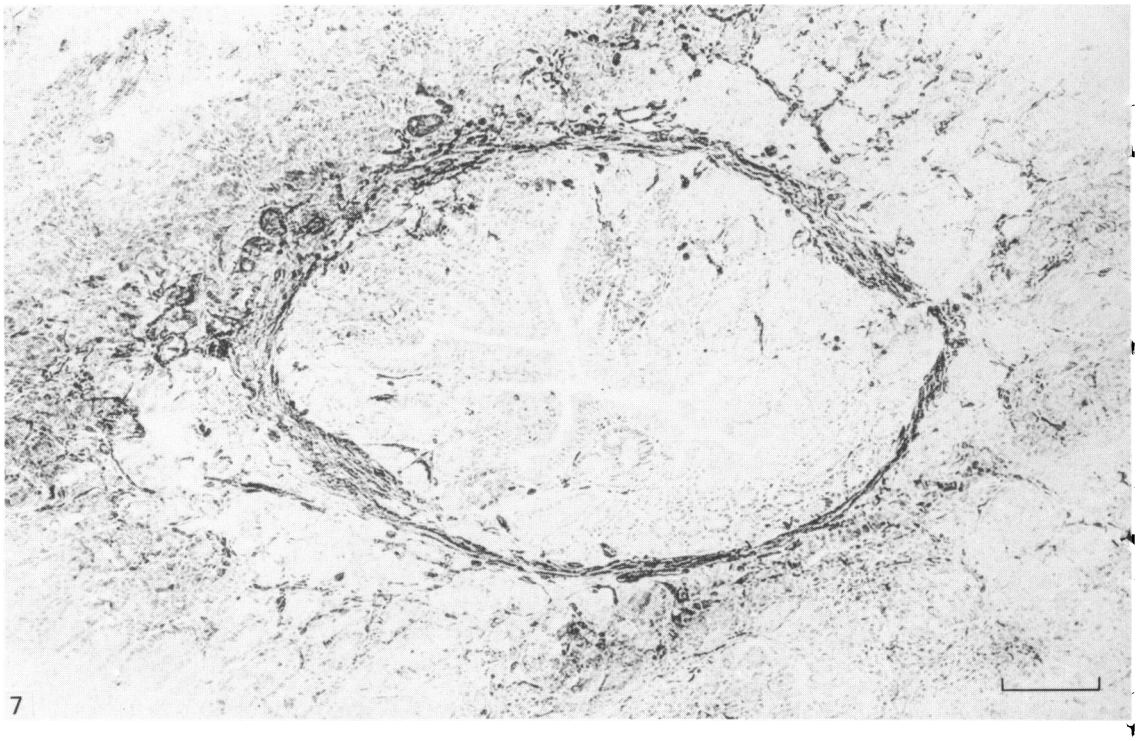


Fig. 6(*a–b*). Whole mount stretch preparations of the mucosal plexus of the gall bladder. (*a*) Stained for acetylcholinesterase. (*b*) Glyoxylic acid fluorescence. Calibration bar: 100 μm.



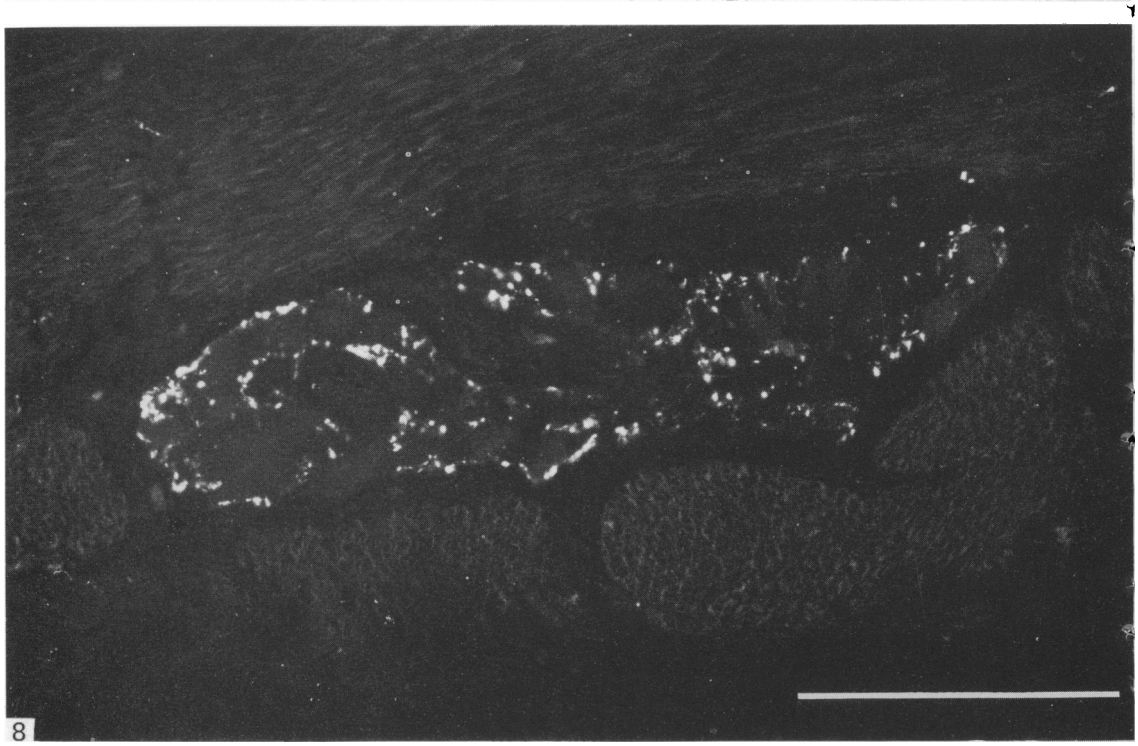


Fig. 7. Transverse cryostat section of the duodenal papilla, stained for acetylcholinesterase and counterstained with haematoxylin and eosin. A ring of smooth musculature receives many nerve fibres and lies close to small nerve ganglia. Calibration bar: 100 μm.

Fig. 8. Section of a large ganglion of the intramuscular plexus in the portion of the common bile duct nearest to the duodenum. Note that fluorescent ganglion cells are absent and the fluorescent varicosities are situated both at the surface of the ganglion and in its deep portions. Glyoxylic acid fluorescence; specimen embedded in Araldite and sectioned at 3 μm. Calibration bar: 50 μm.

A dense nerve plexus ('mucosal plexus') was found in the lamina propria of the gall bladder, between the epithelium and the inner surface of the muscle coat (Fig. 6*a*). A dense innervation was present around the cystic artery and around its branches in the serosa of the gall bladder. There were numerous connexions between the perivascular plexus and the ganglionated plexus.

In the gall bladder, cystic duct, hepatic duct and upper part of the bile duct, intramuscular nerves, as visualised by the cholinesterase reaction, were rare or absent. In the lower portion of common bile duct and in the ampulla, where conspicuous muscle coats were present, there were many intramuscular nerves, both in the circular and the longitudinal muscle layers. The frequency of these intramuscular nerves was comparable to, or somewhat greater than, that found in the muscle coat of the duodenum and of the taenia coli. A rich supply of acetylcholinesterase-positive nerves was also found in the ring of musculature within the papilla (Fig. 7).

All the neurons of the ganglionated plexus displayed acetylcholinesterase activity in the cytoplasm, although the intensity of the reaction varied from one cell to another.

Catecholamine-containing nerves

In stretch preparations of the gall bladder stained with glyoxylic acid (Fig. 5), the ganglion neurons usually displayed no fluorescence. However, some small intensely fluorescent cells and probably a small number of fluorescent neurons were found associated with ganglia and will be described separately. Dense meshworks of brightly fluorescent varicose fibres surrounded the non-fluorescent neurons, forming nests in which the course and branching of individual fibres could not easily be recognised. Fluorescent varicosities were found in all the ganglia of the gall bladder and the biliary pathways. Most of the varicosities appeared close to the surface of ganglion neurons and they were located both near the surface of the ganglia and in their deep portions. Those in the former location were more numerous and larger in size or more intensely fluorescent than the others (Fig. 8).

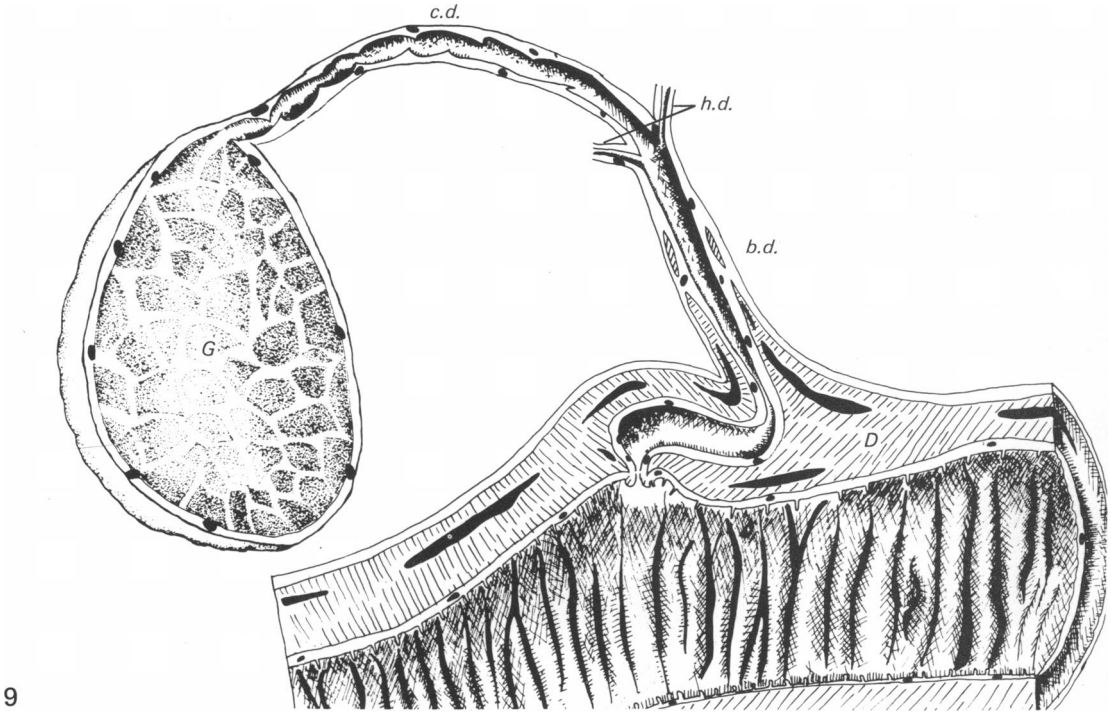
In the connecting strands between ganglia the varicosities were fewer and less intensely fluorescent. Adrenergic fibres also formed a prominent component of the mucosal plexus in the lamina propria (Fig. 6*b*). The cystic artery and its branches were richly supplied with adrenergic fibres while the vein had a few in its adventitia (Fig. 5).

Sections through the wall of the gall bladder showed many fluorescent (adrenergic) fibres on either side of the muscle coat, i.e. in the serosa and in the lamina propria, where they were part of the mucosal plexus. However, hardly any fluorescent fibres were seen within the muscle coat itself.

In the middle and lower portion of the common bile duct and in the ampulla, intramuscular adrenergic fibres were found; they were rare in the longitudinal musculature, and were more common in the circular musculature. They ran parallel to the muscle cells, were varicose and occurred singly. The distribution of the adrenergic innervation was similar to that found in the duodenal musculature. The ganglia were by far the largest found in the biliary system, especially those situated within the musculature of the lowermost part of the common bile duct (Fig. 8).

Enterochromaffin cells

Enterochromaffin cells are very common in the duodenal mucosa (Solcia *et al.* 1981) and they can easily be recognised in fluorescence microscopy by their intense



9

Fig. 9. Schematic drawing showing the distribution of ganglia (black areas) in the gall bladder, the biliary pathways and the duodenum. *G*, gall bladder; *D*, duodenum; *c.d*, cystic duct; *h.d*, hepatic duct; *b.d*, common bile duct.

fluorescence. No enterochromaffin cells have been found in the present study in the mucosa of the gall bladder, of the cystic duct, hepatic duct and of the upper and middle portion of the bile duct; a very small number of fluorescent cells were present in the mucosa of the ampulla and of the lower portion of the common bile duct.

DISCUSSION

The histochemical preparations obtained show that all the portions of the extrahepatic biliary system receive at least two types of nerve fibres, acetylcholinesterase-positive fibres and catecholamine-containing fibres. The nerve supply consists of three components; a ganglionated nerve plexus, a nerve plexus in the adventitia of the cystic artery and its branches, and a nerve plexus in the lamina propria, between muscle coat and epithelium. The ganglionated plexus lies at the *outer* surface of the musculature of the gall bladder, either close to the muscle bundles or in the thick subperitoneal connective tissue (serosa). In this layer lie also the main arteries of the gall bladder, and their adventitial nerve plexus is often seen to exchange adrenergic fibres with the ganglionated plexus. It is worth noting that only by combining observations on whole mount preparations and on transverse sections of the wall can the individuality and the structural features of the three plexuses be analysed fully. In a separate study (Cai *et al.* unpublished observations) these three nerve plexuses were also demonstrated by immunohistochemical methods for neuropeptides. Immunoreactive fibres for vasoactive intestinal polypeptide (V.I.P.) and

substance P were numerous, particularly in the lower part of the bile duct, the ampulla, and the sphincter of the papilla.

The distribution of acetylcholinesterase-positive nerves in the gall bladder of the guinea-pig has been described in detail by Sutherland (1966) and we confirm her findings. As to the adrenergic innervation, we confirm the observations of Baumgarten & Lange (1969) on the absence of intramuscular axons in the gall bladder. However, unlike Baumgarten & Lange (1969) we do find a good number of intramuscular adrenergic fibres in the lower portion of the common bile duct. An abundant intramuscular innervation of the bile duct has also been reported by Mori *et al.* (1971) in guinea-pigs and rabbits, and by Onda & Miyazaki (1980) in the cat and in man. However, the majority of the adrenergic varicosities in the biliary system of the guinea-pig are found in the adventitia of the arteries and in the nerve ganglia. At the latter sites the adrenergic varicosities lie both at the very surface of the ganglion or in its deeper parts, among ganglion neurons. Ultrastructural studies are needed to define the sites of action of these nerve endings. Quantitative studies by Baumgarten & Lange (1969) in rhesus monkeys, and by Onda & Miyazaki (1980) in cats and in man have shown that the lowest concentrations of noradrenaline in the biliary system occur in the bile duct. However, it is difficult to make direct comparisons between fluorimetric and histochemical data, because the different amounts of musculature (and of mucosa) in the various parts of the biliary system may obscure the values of absolute amounts of noradrenaline.

It is worth noting the absence of enterochromaffin cells in the mucosa of the gall bladder and biliary pathways (except for a few cells in the lowest portion of the common bile duct and the ampulla), whereas these cells are extremely numerous in the duodenal mucosa (Solcia *et al.* 1981). The functional significance of this difference is unknown. In view of the complications that the presence of the enterochromaffin cells may present in the biochemical analysis of neuro-active substances, the gall bladder may prove useful as an organ containing a ganglionated plexus and no chromaffin cells. Associated with the plexus of the guinea-pig gall bladder there are, however, a few small intensely fluorescent cells (Sisto & Robecchi, 1968). One should also be aware of wide differences between animal species; for example, enterochromaffin cells have been observed in the human gall bladder (Kyösola & Penttila, 1977).

In another paper we have stressed the quantitative differences in the extent of the musculature within the biliary system (Cai & Gabella, 1983). The present findings indicate that there are similar changes in the extent of the ganglionated plexus. From Table 1 it appears that the plexus has its maximum development where the musculature is thickest, namely in the lowermost part of the common bile duct.

From the lower portion of the common bile duct to the duodenum, there is a conspicuous increase in the thickness of the muscle coat (Cai & Gabella, 1983) and the ganglionated plexus is split into two inter-connected components, one situated close to the inner surface of the muscle coat, the other, far more extensive, being truly intramuscular. The inner component is similar, in the size and distribution of its ganglia, to the plexus of the rest of the biliary pathways and the gall bladder, and it appears in continuity with it (although this point could not be shown too well, because of the difficulty of making stretch preparations of the layers of the bile duct). The inner component of the plexus in the common bile duct is also in continuity with the submucosal plexus of the duodenum. In the accompanying paper it has been pointed out that the musculature of the gall bladder bears some structural similarity

to the muscularis mucosae of the gut. It has been suggested that the musculature of gall bladder, cystic duct, hepatic duct and upper part of the common bile duct may represent an evagination not of the muscularis externa of the duodenum, but of its muscularis mucosae. The present results on the innervation are in agreement with this hypothesis. The ganglionated plexus of the gall bladder is not truly intramuscular but lies at the outer surface of the musculature; if the latter is a derivation of the muscularis mucosae, the subperitoneal connective tissue would be equivalent to the intestinal submucosa (both structures carry the bulk of the vascular supply) and the ganglionated plexus would be equivalent to the submucosal plexus of the intestine and not to the myenteric plexus, as it is generally assumed. Indeed, the pattern of the plexus in the gall bladder and the shape of the ganglia are rather similar to those of the submucosal plexus (Schabadasch, 1930; Ohkubo, 1936; Gunn, 1968; Gabella, 1979), although the size of the ganglia of the gall bladder appears to be more variable, the number of ganglia per unit surface is smaller and the connecting strands are longer. The intramuscular component of the plexus in the common bile duct, on the other hand, is in continuity at one end with the myenteric plexus of the duodenum, while at the other end it does not extend beyond the middle portion of that duct. Because of its connexions, and the size and pattern of its ganglia, it could be regarded as an equivalent of the myenteric plexus.

SUMMARY

The innervation of the gall bladder and the biliary pathways was studied in guinea-pigs by means of histochemical methods for catecholamines and for acetylcholinesterase on whole mount preparations, on cryostat sections and on sections of plastic-embedded tissues.

The gall bladder contains on average 367 neurons in a ganglionated plexus which lies at the outer surface of the muscle coat. The overall appearance of this plexus is rather similar to that of the submucosal plexus of the duodenum. From the gall bladder the plexus extends into the cystic duct, the hepatic duct and the common bile duct, but from the middle portion of the common bile duct downwards, it is positioned at or near the inner surface of the muscle coat. Concurrently with the marked increase in muscle thickness in the lower parts of the common bile duct, another ganglionated plexus appears, which is truly intramuscular. The latter plexus is highly developed, lies usually between longitudinal and circular muscle and resembles in appearance the myenteric plexus of the duodenum, with which it is in continuity. Throughout the biliary system, the extent of the ganglionated plexus is roughly related to the extent of the musculature.

An exchange of adrenergic fibres between the ganglionated plexus and perivascular nerves is observed in the gall bladder. Another nerve plexus, without ganglia but rich in adrenergic and acetylcholinesterase-positive fibres, lies between the mucosa and the muscle coat. Very few nerve fibres run into the musculature of the gall bladder. On the other hand, in the thick musculature of the lower portion of the common bile duct, several intramuscular nerve fibres are found.

We thank Peter Trigg and Eva Franke for excellent technical assistance and the Medical Research Council and the Wellcome Trust for financial support.

REFERENCES

BAUMGARTEN, H. G. & LANGE, W. (1969). Extrinsic adrenergic innervation of the extrahepatic biliary system in guinea-pigs, cats and rhesus monkeys. *Zeitschrift für Zellforschung und mikroskopische Anatomie* **100**, 606–615.

CAI, W. & GABELLA, G. (1983). The musculature of gall bladder and biliary pathways in the guinea-pig. *Journal of Anatomy* **136** (in Press).

DAVISON, J. S., AL-HASSANI, M., CROWE, R. & BURNSTOCK, G. (1978). The non-adrenergic inhibitory innervation of the guinea-pig gallbladder. *European Journal of Physiology* **377**, 43–49.

GABELLA, G. (1979). Innervation of the gastrointestinal tract. *International Review of Cytology* **59**, 129–193.

GRAPULIN, G., OTTOLENGHI, A., FAGIOLO, U. & VECELLIO, A. (1968). Studio sull'innervazione terminale delle vie biliari extraepatiche del cane. Nota III: L'innervazione adrenergica al microscopio a fluorescenza prima e dopo resezione delle vie afferenti vegetative. *Archivio 'De Vecchi' per l'anatomia patologica e la medicina clinica* **51**, 785–790.

GUNN, M. (1968). Histological and histochemical observations on the myenteric and submucous plexuses of mammals. *Journal of Anatomy* **102**, 223–239.

KARNOVSKY, J. M. & ROOTS, L. (1964). A 'direct colouring' thiocholine method for cholinesterase. *Journal of Histochemistry and Cytochemistry* **12**, 219–221.

KYÖSOLA, K. (1974). Cholinesterase histochemistry of the innervation of the smooth muscle sphincters around the terminal intramural part of the ductus choledochus of the dog and cat. *Acta physiologica scandinavica* **90**, 278–280.

KYÖSOLA, K. (1976). Structure and innervation of the choledocho-duodenal junction. *Annales chirurgiae et gynaecologiae Suppl.* **192**, 1–135.

KYÖSOLA, K. (1977). Cholinesterase of the gallbladder. *Histochemistry* **50**, 337–346.

KYÖSOLA, K. (1978). Adrenergic and cholinergic innervation of the supraduodenal common bile duct. *American Journal of Gastroenterology* **70**, 179–183.

KYÖSOLA, K. & RECHARDT, L. (1973). Adrenergic innervation of the choledocho-duodenal junction of the cat and the dog. *Histochemie* **34**, 325–332.

KYÖSOLA, K. & PENTTILA, O. (1977). Adrenergic innervation of the human gallbladder. *Histochemistry* **54**, 209–218.

LINDVALL, O. & BJÖRKLUND, A. (1974). The glyoxylic acid fluorescence histochemical method: a detailed account of the methodology for the visualization of central catecholamine neurons. *Histochemistry* **39**, 97–127.

MORI, J., AZUMA, H. & FUJIWARA, M. (1971). Adrenergic innervation and receptors in the sphincter of Oddi. *European Journal of Pharmacology* **14**, 365–373.

OHKUBO, K. (1936). Studien über das intramurale Nervensystem des Verdauungskanals. II. Die Plexus myentericus und Plexus subserosus des Meerschweinchens. *Japanese Journal of Medical Science* **6**, 21–37.

ONDA, M. & MIYAZAKI, T. (1980). The adrenergic and cholinergic innervation of the gallbladder and extrahepatic biliary duct in the cat and human. *Nippon Shokakibyo Graskai Zasshi (Japan)* **77**, 768–778.

SCHABADASCH, A. (1930). Die Nerven des Magens der Katze. *Zeitschrift für Zellforschung und mikroskopische Anatomie* **10**, 254–385.

SISTO, L. & ROBECCHI, A. (1968). Contribution à l'étude de l'innervation de la vésicule biliaire. *Extrait du Bulletin de l'Association des anatomistes*, 53 Congrès (Tours) **143**, 7–11.

SOLCIA, E., CAPELLA, C., BUFFAC, R., USELLIN, L., FIOCCA, R. & SESSA, F. (1981). Endocrine cells of the digestive system. In *Physiology of the Gastrointestinal Tract* (ed. L. R. Johnson), pp. 39–58. New York: Raven Press.

SOLOVIEVA, I. A. (1980). The structure basis of the peripheral innervation mechanisms in the extrahepatic bile ducts wall. *Sechenov Physiological Journal of USSR* **4**, 571–582.

SUTHERLAND, S. D. (1966). The intrinsic innervation of the gall bladder in *Macaca rhesus* and *Cavia porcellus*. *Journal of Anatomy* **100**, 261–268.

TANSY, M. F., INNES, D. L., MARTIN, J. S. & KENDALL, F. M. (1974). An evaluation of neural influence on the sphincter of Oddi in dog. *American Journal of Digestive Disease* **19**, 423–437.

WAHLIN, T., AXELSON, H., SCHIEBLER, T. H. & WINCKLER, J. (1977). Light and electron microscopic observations of the autonomic innervation of the mouse gallbladder mucosa. *Histochemistry* **53**, 107–116.