

Some observations on the innervation of the human nasopharynx

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INTRODUCTION

The human nasopharynx has been the subject of recent investigation (Ali, 1965, 1967; Khoo, Chia & Nalpon, 1967; Khoo, Kanagasuntheram & Chia, 1967; Kanagasuntheram & Ramsbotham, 1968; Tock & Tan, 1968), but its innervation appears to have received very little attention. A search through the available literature revealed that except for some references on the innervation of the true pharynx (Mitchell, 1953; Ballantyne, Talbert, Currens & Cohen, 1954; Konkin, 1964) there seem to be few details beyond the usual descriptions which are found in the standard text-books of anatomy (e.g. Gardner, Gray & O'Rahilly, 1963; Davies, 1967). It is remarkable that even text-books of neuroanatomy (e.g. Kuntz, 1953; Crosby, Humphrey & Lauer, 1962) do not give a detailed account of the innervation, and it was therefore thought appropriate to present some additional data on the innervation of the human nasopharynx.

MATERIALS AND METHODS

Embryonic and foetal material of the following C.R. lengths, namely 18, 31, 45, 90, 103, 140 and 190 mm, as well as foetuses at 23, 24, 28 and 29 weeks of gestation and two full-term foetuses were available for study. The 18, 31, 45 and 103 mm specimens and one full-term foetus were fixed in 10% formalin, sectioned serially and stained with haematoxylin and eosin. The rest of the material was sectioned fresh; the 90 mm foetus was sectioned serially and some sections were used to demonstrate the distribution of acetylcholinesterase (AChE), while others were treated by a modified Bielschowsky–Gros (Garven & Gairns, 1952) or the Bodian methods. The full-term foetus was stained by the two silver techniques. In all the other foetuses only selected sections of the nasopharynx were stained for study.

The adult unfixed material consisted of five nasopharynges stained by the AChE method alone; two other nasopharynges and one soft palate were processed by the AChE, Bielschowsky–Gros and Bodian methods, while yet another nasopharynx was processed by the fluorescence technique for noradrenaline.

The details of the AChE technique were as follows:

- (1) Fresh frozen sections of the nasopharynx were cut at 25 μ m thickness, forty at a time, mounted in series and fixed in formalin vapour for 30 min.
- (2) The sections were briefly rinsed in three changes of chilled isotonic sodium sulphate.
- (3) The odd-numbered sections were incubated in the substrate, containing

acetylthiocholine iodide, at pH 5.5 with ethopropazine hydrochloride (inhibitor of pseudocholinesterase) at a concentration of 7 mg/1000 ml. The even-numbered sections were divided into two lots. One lot was incubated with 1,5-bis (4 trimethyl ammonium phenyl) pentane-3-one-di-iodide (inhibitor of true cholinesterase) at 6.08 mg/100 ml concentration while the other lot was incubated in the substrate with both inhibitors present and at similar concentrations as stated above. The incubation times for the three groups were similar, varying between 1 and 24 at a room temperature of 22 °C.

(4) The sections were washed for 2 min with deionized water and then treated with sodium sulphide solution in N/5 acetic acid at pH 5.5 for 3 min.

(5) The sections were washed thoroughly with deionized water for 20–30 min, counterstained with cresyl fast violet or neutral red and mounted in the usual manner.

In the quantitative studies a comparison was made of the sizes of the neurons at four stages of development, namely 140 mm, 24 and 28 weeks gestation and adult. A Leitz $\times 6$ ocular specially fitted with a graticule was attached to a Leitz binocular microscope and the longest linear dimension of the neuronal somata in any direction was measured at a final magnification of $\times 280$. All the neurons in the material sectioned were sampled in the 24- and 28-week foetuses and in one adult specimen. In the 140 mm foetus the neurons in about a third of the specimen were studied. In addition all the AChE-negative neurons in the other adult nasopharynges were also measured.

OBSERVATIONS

Ganglia in the nasopharynx

H and E preparations

In the 18 mm embryo, the cells forming the sphenopalatine ganglion (Fig. 1) were related to the distal end of the nerve of the pterygoid canal as well as to the branches of the maxillary division of the trigeminal nerve. The cells of the ganglion

Fig. 1. Transverse section through the pharynx of the 18 mm c.r. length embryo to show the scattered cells (arrow) of the sphenopalatine ganglion. Note nerve bundles supplying the roof of pharynx. (H and E.)

Fig. 2. Perimuscular ganglion (arrow) in the wall of the nasopharynx along the IXth nerve in the 45 mm c.r. length foetus. (H and E.)

Fig. 3. Ganglion cells along the nerve of the pterygoid canal in the 45 mm c.r. length foetus. (H and E.)

Fig. 4. An isolated ganglion cell along the nerve of the pterygoid canal in the same foetus as above. (H and E.)

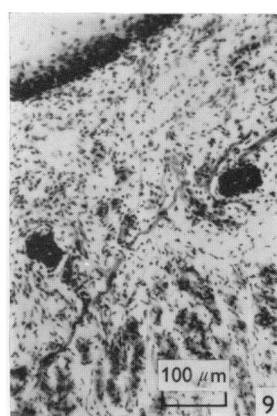
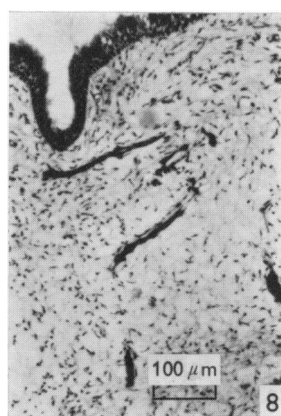
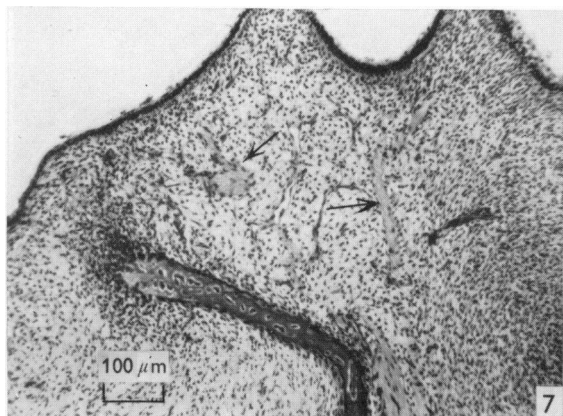
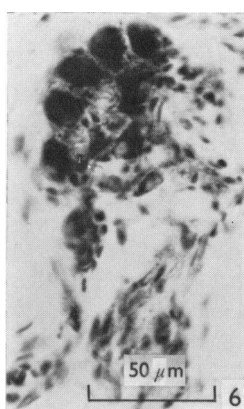
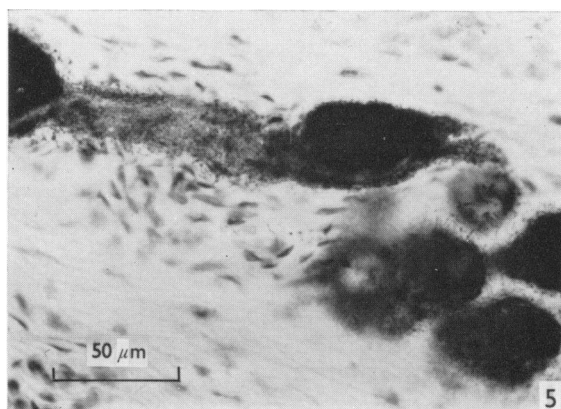
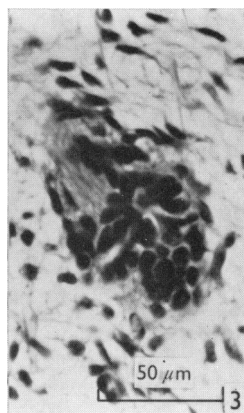
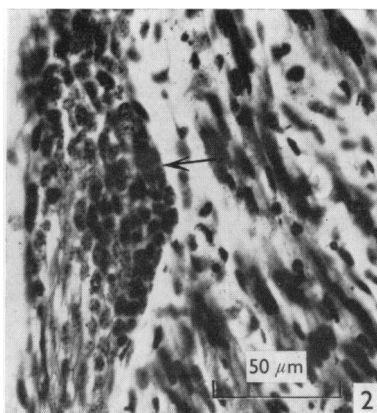
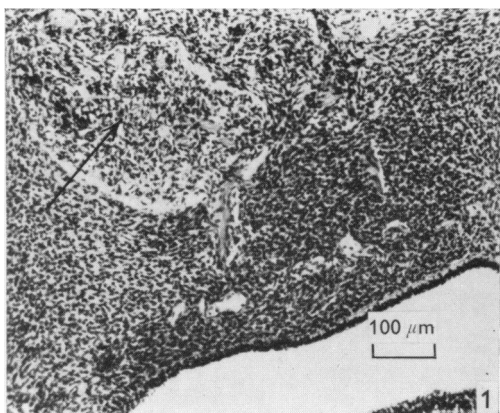
Fig. 5. Paraglandular ganglion in the adult nasopharynx, AChE method, incubation time 2½ h. Note cholinergic fibres extending between ganglion cells.

Fig. 6. Paraglandular ganglion in full term foetus. AChE method, incubation time 2½ h.

Fig. 7. Coronal section through the nasopharynx of 45 mm c.r. length foetus to show the subdivisions of nerve bundles (arrows) on the upper surface of the soft palate. (H and E.)

Fig. 8. Coronal section through the roof of the nasopharynx to show the presence of large cholinergic bundles in 90 mm foetus. AChE method, incubation time 2½ h.

Fig. 9. Cholinergic fibres in the submucosa of the nasopharynx in 150 mm foetus. AChE method, incubation time 2½ h.



were somewhat smaller than those of the glossopharyngeal (IXth) nerve ganglia rounded or polygonal in shape arranged in scattered islets; cells of the IXth nerve ganglia were mostly rounded or oval, grouped together and more tightly packed. The cells of all the ganglia were dark staining. An occasional large cell equalling the size of the IXth nerve ganglion cells was present along the course of the nerve of the pterygoid canal.

In the 31 mm embryo the sphenopalatine ganglion was elongated in the dorso-ventral direction and presented a more compact appearance than in the preceding stage. Many cells were lightly stained, while a few still stained darkly. Some cells were seen along the course of the nerve fibres leaving the sphenopalatine ganglion, not far removed from the main ganglion. Some large isolated eosinophilic cells resembling nerve cells found around the nasopharynx had no connexion with nerve fibres so far as could be made out in H and E sections. Of special interest was a binucleated eosinophilic neuron lying along the proximal part of one of the nerves leaving the ganglion. The cells of the ganglion were distinctly smaller than those of the inferior ganglion of the IXth nerve. The superior ganglion of the IXth nerve was composed chiefly of dark-staining cells contrasting with the lighter-staining cells of the inferior ganglion.

In the 45 mm foetus the sphenopalatine ganglion showed features similar to the preceding stage except that the cells were somewhat larger. Isolated cells resembling ganglion cells which were present in the 31 mm stage were now practically absent. The superior and inferior ganglia of the IXth nerve now resembled one another in their staining intensity. In the wall of the nasopharynx large collections of cells were present in relationship to the fibres of the IXth nerve (Fig. 2), and submucous ganglia could also be observed. Ganglion cells smaller than those of the main sphenopalatine ganglion were present along the nerve of the pterygoid canal (Fig. 3), but an abnormally large and mature cell with satellite cells was present along the course of the nerve (Fig. 4). The larger branches of the maxillary nerve which issued from the sphenopalatine ganglion to be distributed to the palate and anterior part of the nasopharynx had ganglion cells at their proximal ends.

In the 103 mm foetus some fibres of the IXth nerve appeared to end in the superior constrictor; other branches penetrated the muscular coat, and a series of ganglia was found along their course within the submucosa. Ganglia were also present on the lateral surface of the superior constrictor muscle. The cells of the latter were somewhat smaller than those of the sphenopalatine ganglion, while the cells of the IXth nerve ganglia were larger than those of the sphenopalatine ganglion. Isolated ganglion cells were also observed on the upper surface of the hard palate, and larger ganglia were found along the preterminal branches of the IXth nerve supplying the posterior portions of the soft palate.

Cholinesterase preparations

(a) *Qualitative.* The adult material (Fig. 5) is described first as this will serve as a reference for less mature stages. In all the material examined AChE-positive neurons predominated, and the number of AChE-negative neurons in any nasopharynx was small. The intensity of the reaction varied in different cells, and the differentiation of

slightly positive cells from unstained elements was often difficult. The reaction was confined to the neuronal cytoplasm; nuclei and satellite cells were unstained.

The neurons were arranged in three sites but the boundaries of these were not clearly defined. Typically, neurons in the *subepithelial* position, i.e. very near to the lumen, appeared singly or in groups of 2–4, and occasionally more. *Paraglandular* nerve cells adjacent to the many glands in the nasopharynx appeared commonly in groups of variable numbers up to 35 neurons. The third situation in which neurons were found was *myenteric*, in the interspaces between the striated muscle bundles. Here many neurons lay within nerve bundles, but the number in a group was less than in the paraglandular position. The sizes of the neuronal somata also varied, ranging from about 15 μm in longest diameter to over 60 μm . The impression that the AChE-negative neurons were always in the smaller range was later confirmed by measurement. The cell bodies were usually either circular or oval, a few were elongated or fusiform.

Table 1. Long diameters (μm) of neuronal somata of the nasopharynx in the four stages examined

Specimen	AChE + ve				AChE - ve			
	Number	Range (μm)	Mean (μm)	S.D.	Number	Range (μm)	Mean (μm)	S.D.
Adult	200	17–67.5	38.14	± 8.67	47	11.25–45	21.84	± 4.57
28th week	188	5–30	13.01	± 4.30	23	3.75–15	7.8	
24th week	24	5–15	8.44		9	5–11.25	7.14	
140 mm	79	6–15	8.59	± 2.01	15	5–11.25	9.57	

The staining characteristics of the foetal material (Fig. 6) resembled that in the adult except that the intensity was less for similar incubation times. AChE-positive neurons were seen in all the three foetal stages examined. In the foetal stages more neurons were present in a myenteric position than in the other two situations.

(b) *Quantitative*. Altogether in the four stages 585 neuronal somata were measured, all of which showed the nucleus and nucleolus. Only the histochemical reaction of the neurons and not their anatomical features has been taken into account. The number of neurons measured in each stage, the ranges of long diameters, the mean long diameters and the standard deviations (s.d.) are given in Table 1.

AChE-positive neuronal somata have greater ranges as well as greater average long diameters than AChE-negative neurons in the same stages. Thus in the adult stage as shown in the percentage histograms (Figs. 10A, B) there is a 'shift to the left' in the case of AChE-negative neurons. In this figure also the gradual shifting of the modes in D, C, and A to the right from the immature stages to the adult is shown. At the 140 mm stage fifty-five of seventy-nine AChE-positive neurons sampled (69.6%) fell within the range 0–9 μm in long diameter, whereas in the adult specimen no neuron was found within this range. Taking the averages at these two stages there is a fourfold increase in the long diameter between the 150 mm stage and the adult. In general the long diameter probably gave a fair indication of the relative sizes of neurons as most were circular or oval in cross-section, although a negligible

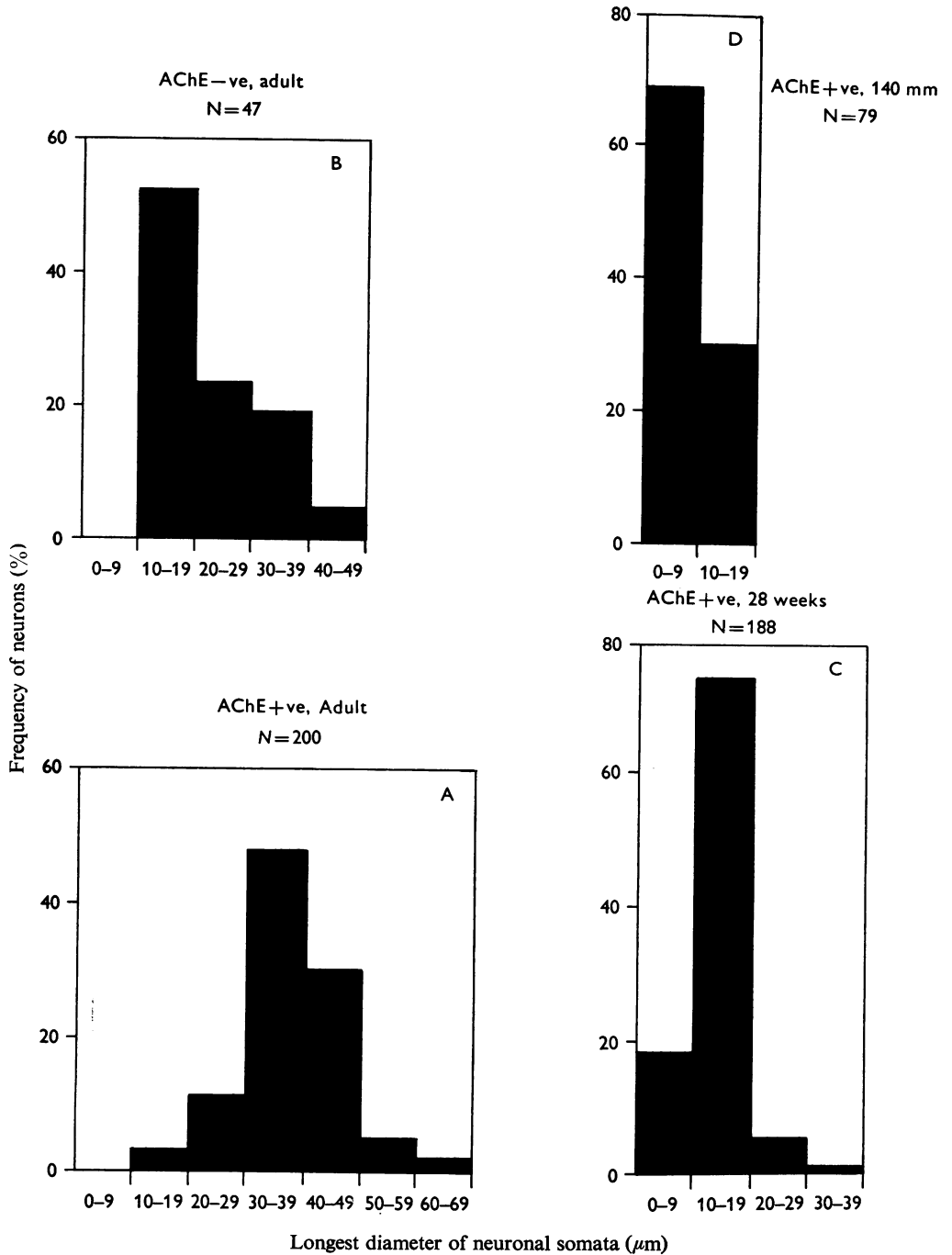


Fig. 10. Percentage histograms of the frequency distribution of the long diameters of neurons of the nasopharynx at two foetal stages of development and in the adult nasopharynx.

number were fusiform in shape, so that the measurement of the long diameter alone in such instances was a less accurate index than in the majority.

Nerve plexuses and nerve terminations of the nasopharynx

Embryonic and foetal material

In the 18 mm embryo no real plexuses were seen but two branches to the future nasopharynx were given off from the region of the sphenopalatine ganglion (Fig. 1). In the 31 and 45 mm specimens the main branches derived from the region of the sphenopalatine ganglion showed further subdivisions before terminating in the submucosa (Fig. 7), whereas branches arising from the communicating sympathetic branches (to the greater superficial petrosal nerve) were thick and of almost uniform diameter throughout. The fascicles from the latter nerve also terminated in the submucous tissue without further subdivisions, but these endings lay further from the epithelium than those fascicles derived from the sphenopalatine ganglion. The 90 mm foetus showed large AChE-positive bundles terminating in the submucous tissue (Fig. 8). No AChE positive fibres were seen reaching the basal layer of the epithelium (Figs. 8, 9), but in contrast, Bielschowsky and Bodian preparations of the same stage showed that fine or medium sized fibres did extend to the basal layer of the epithelium (Fig. 11). The perimuscular plexus was well developed in the 45 mm foetus (Fig. 12) while the submucous plexus became clearly demarcated in the 90 and 103 mm stages.

Adult material

In silver preparations the intramuscular bundles consisted chiefly of thick myelinated fibres and a few thin ones (Fig. 13). As the bundles reached the submucous region they were much thinner but still mainly myelinated (Fig. 14). Most preparations did not reveal fine fibres in the submucosa nor among the gland lobules. Moreover, fibres in Bielschowsky preparations appeared to be thicker than corresponding fibres in Bodian preparations.

AChE-positive neurons were present in the submucosa, and silver preparations revealed complex plexus formation within these submucous ganglia (Figs. 15, 16). In some of these, medium-sized myelinated fibres were seen towards the superficial part of the plexus, while fine fibres in large numbers were seen to emerge from its deep portion. AChE preparations revealed many cholinergic fibres (Fig. 17) between gland lobules and lobes not only in the submucosa but also in the muscle coat. Most arteries were surrounded by cholinergic fibres (Fig. 18), but a small proportion showed a negative reaction. In one specimen the fluorescence technique showed noradrenergic terminals in the walls of some of the arteries.

In general more nerve endings, both simple and organized, were encountered over the caudal part of the nasopharynx lined by stratified squamous epithelium than over the cranial portion in which there was a predominance of columnar ciliated epithelium. In the epithelium the nerve endings were simple and were of many varieties. In one type a myelinated fibre was found to lose its myelin sheath and terminate as a naked ending either in the basal layer or between the cells of the epithelium. The myelinated fibre was often accompanied by a thin fibre which terminated in the basal

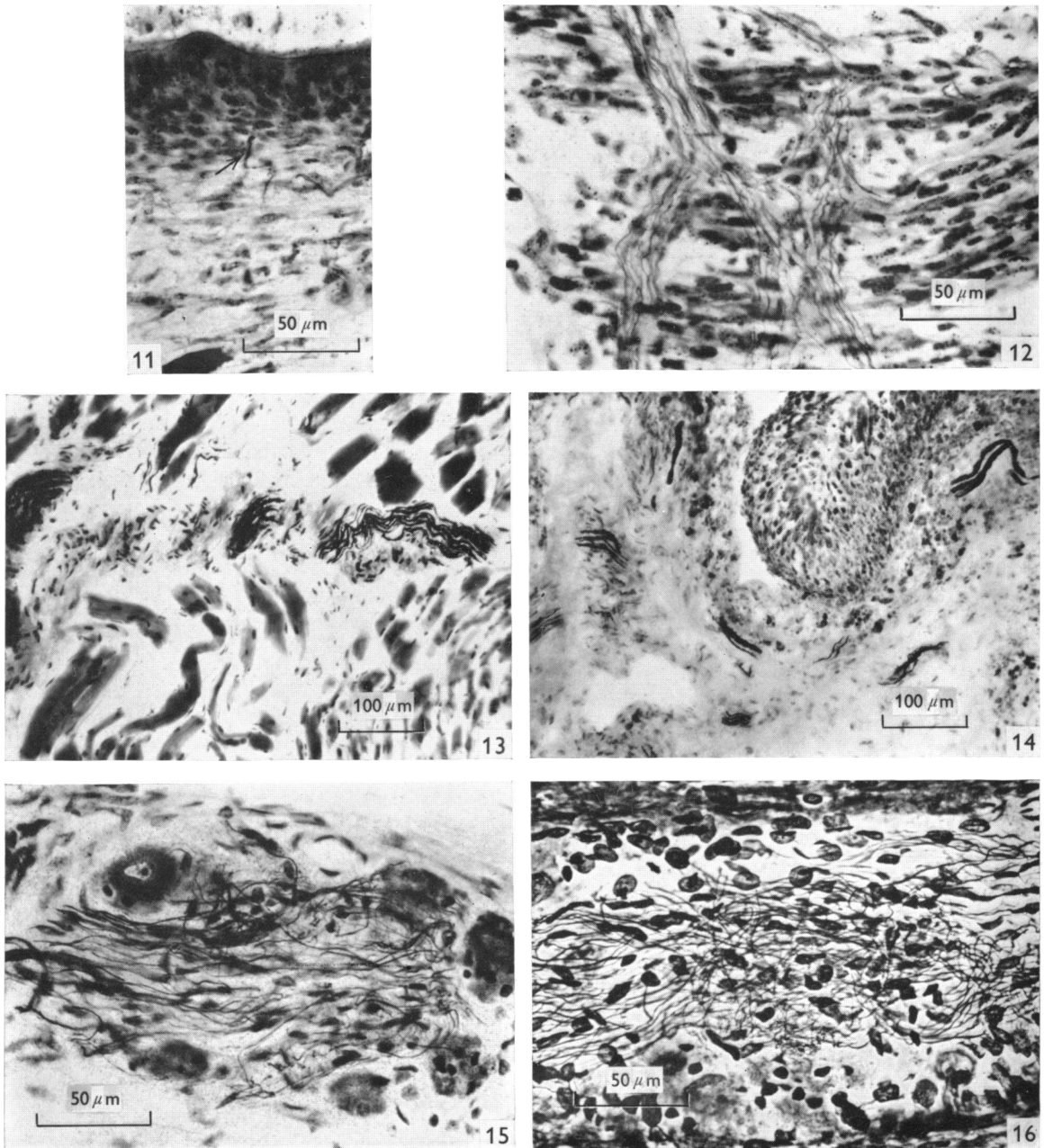


Fig. 11. Bielschowsky preparation, showing a nerve fibre with a bulbous termination (arrow) in the mucosa of the nasopharynx in the 90 mm foetus.

Fig. 12. Bodian preparation to show intermuscular plexus in nasopharynx of the 45 mm. c.r. length foetus.

Fig. 13. Bielschowsky preparation showing the intramuscular plexus in adult nasopharynx.

Fig. 14. Submucous nerve bundles in adult nasopharynx. Bielschowsky preparation.

Fig. 15. Bielschowsky preparation to show the fine fibres in a paraglandular ganglion in adult nasopharynx.

Fig. 16. Bodian preparation to show the same as above.

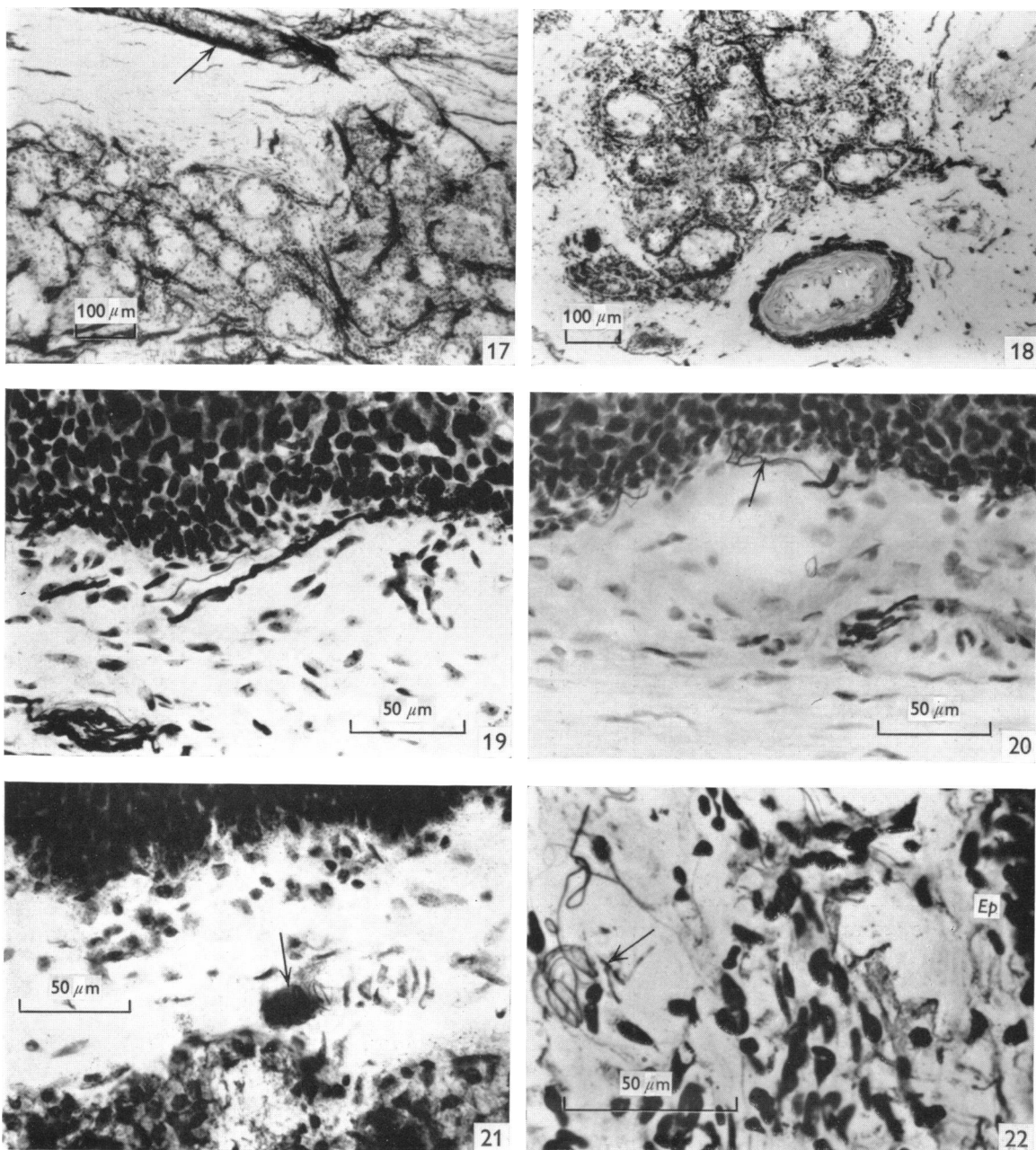


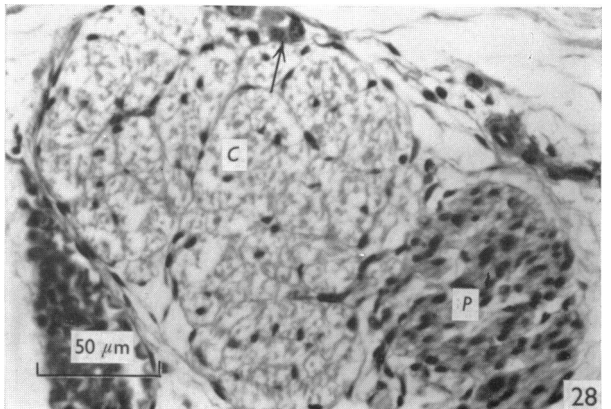
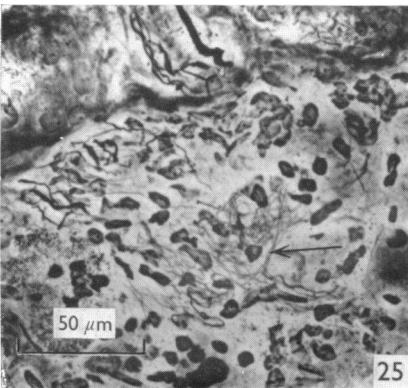
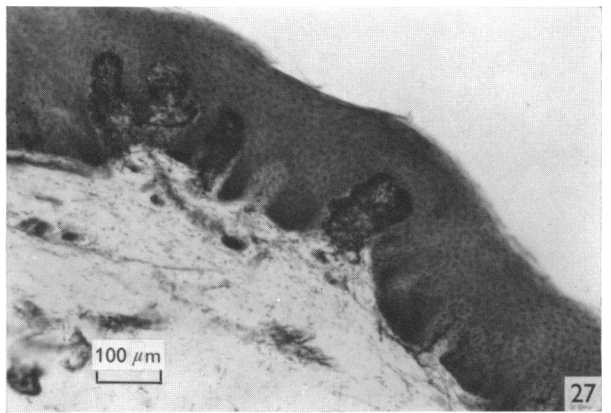
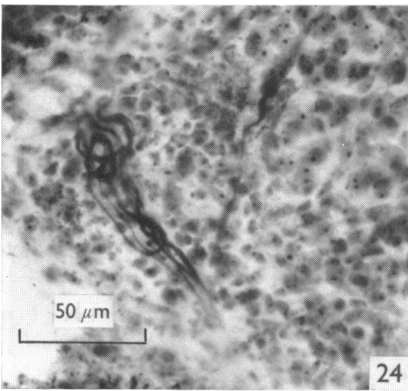
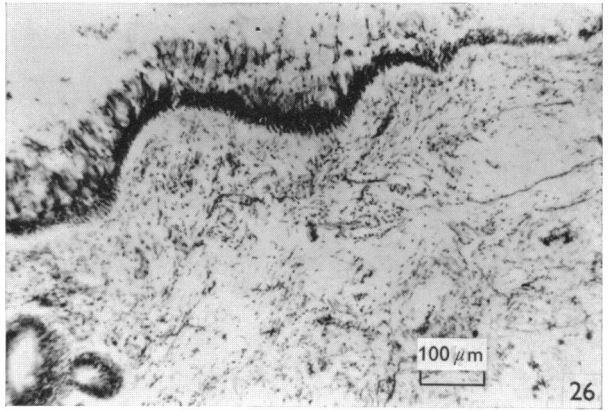
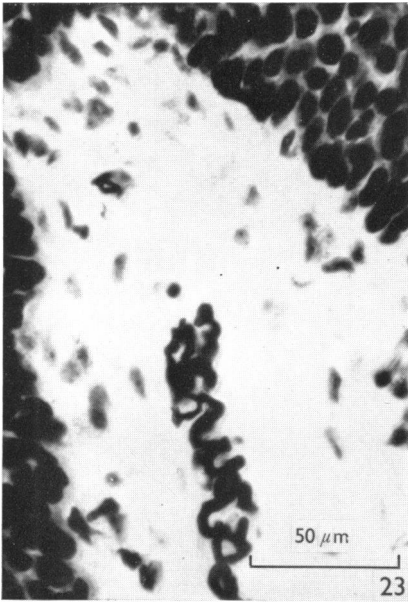
Fig. 17. Cholinergic bundles between acini and lobules in adult nasopharynx. Note cholinergic fibres along the blood vessel cut longitudinally (arrow.) AChE method, incubation time, 20 h.
 Fig. 18. Same as above to show cholinergic nerve fibres around wall of an arteriole. AChE method, incubation time 20 h.

Fig. 19. Bielschowsky preparation showing thick and thin fibres ending on the under surface of the epithelium of adult nasopharynx.

Fig. 20. Bielschowsky preparation showing a fine fibre (arrow) running parallel to the basal layer of the epithelium and sending terminals in between the basal cells. Adult nasopharynx.

Fig. 21. Bielschowsky preparation showing a tightly coiled nerve ending (arrow) in the submucosa of adult nasopharynx.

Fig. 22. Bodian preparation showing coiled nerve endings (arrow) in the submucosa. Adult nasopharynx. Ep. = epithelium.



layer of the epithelium (Fig. 19). In another type myelinated fibres terminated on the under surface of the epithelium. Other varieties included thin fibres passing either immediately below the epithelium or in contact with the cells of the basal layer (Fig. 20), and some ended in brush-like expansions or bulbous endings within the basal layer. Some thin fibres formed a plexus underneath the epithelium giving branches to the latter.

Simple and organized endings were present in the sub-epithelial connective tissue. For example, some nerve fibres underwent repeated coiling before actually terminating (Figs. 21, 22); two myelinated fibres passed towards a papilla and formed a complex spiral pattern resembling a Meissner's corpuscle (Figs. 23, 24); fibres seemed to end as bulbous expansions in the papillae; sometimes two or three fibres left the submucous plexus and ascended vertically to end abruptly in the lamina propria without showing any marked reduction in their size. It was difficult to be certain with the methods used whether the endings described were true terminations. In some sites a group of fibres formed a ball-like structure immediately beneath the epithelium within the papilla of the lamina propria. Each complex was usually made up entirely of fine fibres (Fig. 25) forming a fibrillar reticulum, while occasionally both myelinated and unmyelinated fibres were encountered. There were nerve fibres in the lamina propria and some in relationship to glands that became attenuated and terminated as pointed endings.

In AChE preparations single fibres were seldom seen terminating in the epithelium. However, several AChE-positive fibres lying either singly or in groups, were found within the lamina propria a short distance below the epithelium (Fig. 26), unrelated to any blood vessels. Many cholinergic fibres were found to be in relationship to blood vessels, gland lobules (Figs. 17, 18) and capillaries, and it was difficult to determine whether these formed actual terminations in the papillae of the lamina propria or whether they were merely related to blood vessels passing towards the epithelium. On the undersurface of the soft palate, however, AChE-positive fibres did form complex nerve endings within the papillae (Fig. 27). A comparison with silver preparations showed that the AChE activity was related to the organized endings on the undersurface of the soft palate.

Fig. 23. Bielschowsky preparation showing an organized nerve ending composed of thick fibres lying within a papilla of the lamina propria in adult nasopharynx.

Fig. 24. Bielschowsky preparation showing another type of organized nerve ending composed of thick and thin fibres situated within a papilla of the lamina propria in adult nasopharynx.

Fig. 25. Bodian preparation showing a neurofibrillar reticulum (arrow) in the submucosa. Adult nasopharynx.

Fig. 26. AChE preparation showing cholinergic fibres unrelated to blood vessels in the submucosa. Incubation time 2½ h. Adult nasopharynx.

Fig. 27. Organized nerve terminals showing positive AChE reaction situated within the lamina propria of the papillae on the under surface of the soft palate. Incubation time 20 h. Adult material.

Fig. 28. H and E preparation of the sympathetic component (C) along the greater superficial petrosal nerve (P) in 103 mm foetus. Note the difference in the staining reaction of the two component parts of the nerve of the pterygoid canal and some ganglion cells situated near the periphery of the sympathetic component (↑).

Extrinsic nerve supply of the nasopharynx

The anterior part of the nasopharynx including the upper part of the soft and hard palates is supplied by branches from the maxillary nerve that pass through the sphenopalatine ganglion. The most posterior part of the soft palate, however, derives its supply from the main trunk of the IXth nerve as the latter skirts round the tonsil. Some of the fibres (possibly sensory) coming from the posterior end of the sphenopalatine ganglion supply the nasopharynx up to the tubal orifice while others pass behind the origin of the tube.

The posterior part of the nasopharynx is supplied by branches from the so-called sympathetic contribution from the internal carotid nerve to the greater superficial petrosal nerve. In all embryos and fetuses examined (18–103 mm) two or three fascicles were seen arising from the internal carotid nerve. These fascicles, either at their point of union with the greater superficial petrosal nerve, or sometimes after joining the latter nerve, gave branches to the posterior part of the nasopharynx. A communicating branch, either from the inferior ganglion of the IXth nerve or the upper part of the nerve trunk itself joined the internal carotid nerve prior to the origin of the sympathetic fascicles which later join the greater superficial petrosal nerve. Moreover, the tympanic branch of the IXth nerve gave a direct communicating branch to the greater superficial petrosal nerve as the latter emerged from the geniculate ganglion.

The so-called sympathetic contribution which joins the greater superficial petrosal nerve was almost twice as large as the greater superficial petrosal nerve itself (Fig. 28) and was strongly AChE-positive in comparison to the greater superficial petrosal nerve. The main maxillary nerve in the 90 mm foetus was AChE-negative. On the greater superficial petrosal nerve, as well as along the course of the nerve of the pterygoid canal, ganglion cells were found either singly or in clusters; these were AChE-positive in the 90 mm foetus.

DISCUSSION AND CONCLUSIONS

Ganglia of the nasopharynx

Migration of cells along the course of various nerves is said to result in the formation of the sphenopalatine and other parasympathetic ganglia such as the ciliary, otic and submandibular ganglia (Kuntz, 1953). Hence it would appear that migration of cells along the nerves leaving the sphenopalatine ganglion would give rise to the ganglia in the anterior roof of the nasopharynx and palate, while cells presumably migrate along the branches of the IXth nerve to form the intramuscular, submucous and subepithelial ganglia observed within the rest of the nasopharynx. Indeed, the findings in the 31 and 45 mm specimens do support such a view. Moreover, our observations show that the various ganglia become established by the 45 mm stage if not earlier. The fact that the smaller neurons at this stage occupy a sub-epithelial position while large ones are present more peripherally might indicate that neurons complete their maturation after they have reached their final destination. However, the presence of a large ganglion cell with satellite cells along the course of the nerve of the pterygoid canal suggests that some neurons undergo precocious development.

The presence of AChE-positive neurons in the 90 mm foetus might indicate early functional activity on the part of the glands of the nasopharynx. Most of the neurons within the nasopharynx are AChE-positive, but differences in the intensity of staining even in the same specimen might mean that they are in different states of activity or of different degrees of maturity. Some of them might indeed be sympathetic neurons, since the latter also exhibit a weak positive reaction for AChE (Schofield, 1962). The few unstained neurons are invariably small, and are interpreted as immature. However, the possibility that some of these could be sensory and mediate local reflex activity concerned with secretion of the glands in response to various stimuli must also be considered. A similar view regarding some of the enteric neurons has been advanced by Bülbring, Lin & Schofield (1958) and Schofield (1960).

Nerve plexuses and terminals

The present observations show that the muscular plexuses appear in the caudal part of the nasopharynx by the 45 mm stage, while the submucous plexus and the nerve terminations reaching the mucosa are developed by the 90 mm stage. Nerve terminals thus seem to develop within the nasopharynx somewhat earlier than in the human hand, where they appear by about the 5th foetal month (Cauna & Mannan, 1961). It must, however, be emphasized that only simple nerve endings are seen in the nasopharynx in the 90 mm stage. In fact, even the adult nasopharynx contains only a few organized endings, which according to the definition of Sinclair, Weddell & Zander (1952) include 'any closely knit and well localized nerve terminations (other than a single terminal bead) whether or not it is surrounded by a connective tissue bed'. The presence of only a few organized endings in the nasopharynx is in contrast to the numerous organized terminations that are found in the human skin (Cauna, 1956, 1959; Weddell, Palmer & Pallie, 1955) and in the gums and oral mucosa (Gairns & Aitchison, 1950; Gairns, 1955; Dixon, 1957, 1961). However, this scarcity is not surprising since the nasopharynx is a part of the primitive pharynx, and is mostly entodermal in origin, whereas the oral mucosa is chiefly, and the skin entirely ectodermal in origin.

Various types of free nerve endings similar to some of those described in the skin (Cauna 1959) and oral mucosa (Dixon, 1961) are also present in the nasopharynx. The type in which a thick medullated fibre is accompanied by a thin fibre has been described by Woollard, Weddell & Harpman (1940) and Weddell (1945); these authors believe that the thick fibre is concerned in the mediation of touch impulses while the thin fibre is for the propagation of pain impulses. By contrast, however, Bishop (1959) has suggested that the thinner fibre may be related to the mediation of touch impulses. Such a concept goes against the theory of specific nerve energies which has since been repudiated by Weddell *et al.* (1955) and Sinclair (1955), although this should not be interpreted to mean that some of the complex organized endings such as the Meissner's corpuscles are concerned in subserving more than a single sensory function.

The submucous nerve bundles show a positive AChE reaction in the 90 mm foetus whereas the nerve terminals reaching the mucosa are AChE-negative. A similar observation was also made in the adult material, particularly from the roof of the nasopharynx. The presence of AChE-positive nerve bundles in the corium during foetal

stages has been observed in the developing human hand by Beckett, Bourne & Montagna (1956) and Cauna & Mannan (1961). However, according to the latter authors the nerve bundles become AChE-negative in adult material, a finding which seems to differ from our present investigations. It is therefore possible that the human adult nasopharynx retains the foetal and hence a more primitive condition.

Extrinsic innervation of the nasopharynx

Regarding the extrinsic nerve supply it is stated (Hollinshead, 1958; Gardner *et al.* 1963; Grant & Basmajian, 1965) that the IXth nerve provided the sensory supply to the entire nasopharynx except the anterior portion of the soft palate and a limited superior portion of the nasopharynx in front of the tubal orifice. However, none of the above authors describe the course of the branches of the IXth nerve supplying these regions of the nasopharynx. From our observations it is possible to state that the fibres of the IXth nerve supplying the posterior roof of the nasopharynx are conveyed by two routes: (1) via the so-called communicating sympathetic branches which join the greater superficial petrosal nerve, and (2) via the greater superficial petrosal nerve which receives a communication from the tympanic branch of the IXth nerve. In this way the IXth nerve is able to supply the roof of the nasopharynx up to the tubal orifice or even invade the territory anterior to this orifice. Such a pattern of supply is in accordance with the anterior migration of the 3rd arch during the development of the tubotympanic recess (Kanagasuntheram, 1967). The branches carrying the nerve fibres supplying the roof of the nasopharynx may arise either directly from the communicating sympathetic fascicles joining the greater superficial petrosal nerve, or from the nerve of the pterygoid canal, or may even be represented by the so-called pharyngeal branch of the sphenopalatine ganglion. Finally, the present observations confirm the fact that the posterior part of the soft palate is innervated by direct branches from the IXth nerve as the latter skirts around the tonsillar bed.

SUMMARY

Embryonic, foetal and adult material stained by H and E, Bodian, modified Bielschowsky-Gros and AChE methods have been used to investigate the nerve supply of the human nasopharynx.

The submucous, intramuscular and perimuscular ganglia of the nasopharynx make their appearance by the 45 mm stage or earlier. AChE-positive neurons are present in the 90 mm foetus, indicating an early functional activity of these neurons. In the adult nasopharynx, AChE-positive neurons predominate but some neurons are AChE-negative or only weakly positive. Occasionally, there is a precocious development of neurons along the course of the greater superficial petrosal nerve.

The main nerve bundles supplying the nasopharynx undergo repeated subdivision in the 45 mm foetus while the submucous plexus becomes established by the 90 mm stage. At this latter stage, only simple nerve endings are present within the nasopharynx.

In the adult, simple nerve terminations predominate; there are also a few organized but unencapsulated endings more frequently found in the caudal part of the nasopharynx which is lined by stratified squamous epithelium.

The so-called sympathetic contribution to the greater superficial petrosal nerve from the internal carotid nerve carries cholinergic and possibly afferent fibres to the

nasopharynx from the IXth nerve which sends a communicating branch to the internal carotid nerve. IXth nerve fibres may also reach the nasopharynx by another communicating twig from the tympanic branch of the IXth nerve to the greater superficial petrosal nerve.

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REFERENCES

- ALI, M. Y. (1965). Histology of the human nasopharyngeal mucosa. *J. Anat.* **99**, 655-672.
- ALI, M. Y. (1967). Distribution and character of the squamous epithelium of the human nasopharynx. In *Union Internationale Contre le Cancer* (Monograph series), **1**, 138-146. Copenhagen: Munksgaard.
- BALLANTYNE, H. T., JR., TALBERT, R., CURRENS, J. H. & COHEN, M. E. (1954). Studies of sensation, circulation and respiration after bilateral glossopharyngeal rhizotomy. *Trans. Am. Neur. Ass.* **79**, 69-72.
- BECKETT, E. B., BOURNE, G. H. & MONTAGNA, W. (1956). Histology and cytochemistry of human skin. The distribution of cholinesterase in the finger of the embryo and the adult. *J. Physiol., Lond.* **134**, 202-206.
- BISHOP, G. H. (1959). The relation between nerve fibre size and sensory modality: phylogenetic implications of the afferent innervation of cortex. *J. nerv. ment. Dis.* **128**, 89-114.
- BÜLBRING, E., LIN, R. C. Y. & SCHOFIELD, G. (1958). An investigation of the peristaltic reflex in relation to anatomical observations. *Q. Jl exp. Physiol.* **43**, 26-37.
- CAUNA, N. (1956). Structure and origin of the capsule of Meissner's corpuscles. *Anat. Rec.* **124**, 77-94.
- CAUNA, N. (1959). The mode of termination of the sensory nerves and its significance. *J. comp. Neur.* **113**, 169-210.
- CAUNA, N. & MANNAN, G. (1961). Organization and development of the preterminal nerve pattern in the palmar digital tissues of man. *J. comp. Neurol.* **117**, 319-327.
- CROSBY, E. C., HUMPHREY, T. & LAUER, E. W. (1962). *Correlative Anatomy of the Nervous System*. New York: Macmillan.
- DAVIES, D. V. (1967). *Gray's Anatomy*, 34th ed. London: Longmans Green and Co. Ltd.
- DIXON, A. D. (1957). Nerve plexuses in the oral mucosa. *J. dent. Res.* **36**, 807.
- DIXON, A. D. (1961). Sensory nerve terminations in the oral mucosa. *Archs oral. Biol.* **5**, 105-114.
- GAIRNS, F. W. (1955). The sensory nerve endings of the human palate. *Q. Jl exp. Physiol.* **40**, 40-48.
- GAIRNS, F. W. & AITCHISON, J. (1950). A preliminary study of the multiplicity of nerve endings in the human gum. *Dent. Res.* **70**, 180-193.
- GARDNER, E., GRAY, D. J. & O'RAHILLY, R. (1963). *Anatomy: A Regional Study of Human Structure*. Philadelphia and London: W. B. Saunders.
- GARVEN, G. S. D. & GAIRNS, F. W. (1952). Silver diamine ion staining of peripheral nerve elements and the interpretation of the results, with a modification of the Bielschowsky-Gros method for frozen sections. *Q. Jl exp. Physiol.* **37**, 131-142.
- GRANT, J. C. B. & BASMAJIAN, J. V. (1965). *Grant's Method of Anatomy*, 7th ed. Baltimore: The Williams and Wilkins Co.
- HOLLINSHEAD, W. H. (1958). *Anatomy for Surgeons*. Vol. I, *The Head and Neck*. New York: Hoeber-Harper.
- KANAGASUNTERAM, R. (1967). A note on the development of the tubotympanic recess in the human embryo. *J. Anat.* **101**, 731-742.
- KANAGASUNTERAM, R. & RAMSBOTHAM, M. (1968). Development of the human nasopharyngeal epithelium. *Acta anat.* (in the Press).
- KHOO, F. Y., KANAGASUNTERAM, R. & CHIA, K. B. (1967). Variations of the lateral recesses of the nasopharynx. *Arch. Otolaryng.* **88**, 456-462.

- KHOO, F. Y., CHIA, K. B. & NALPON, J. (1967). A new technique of contrast examination of the nasopharynx with cinefluorography and roentgenography. *Am. J. Roentg.* **99**, 238–248.
- KONKIN, I. F. (1964). Structure of pharyngeal nerve plexuses. *Fedn Proc. Fedn Am. Socs exp. Biol.* **23**, 617–620.
- KUNTZ, A. (1953). *The Autonomic Nervous System*. Philadelphia: Lea and Febiger.
- MITCHELL, G. A. G. (1953). *Anatomy of the Autonomic Nervous System*. Livingstone: Edinburgh.
- SCHOFIELD, G. C. (1960). Experimental studies on the innervation of the mucous membrane of the gut. *Brain* **83**, 490–514.
- SCHOFIELD, G. C. (1962). Experimental studies on the myenteric plexus in mammals. *J. comp. Neurol.* **119**, 159–186.
- SINCLAIR, D. C. (1955). Cutaneous sensation and the doctrine of specific energy. *Brain* **78**, 584–614.
- SINCLAIR, D. C., WEDDELL, G. & ZANDER, E. (1952). The relationship of cutaneous sensibility to neurohistology in the human pinna. *J. Anat.* **86**, 402–411.
- TOCK, E. P. C. & TAN, N. T. S. (1968). A histochemical study of the mucins of the adult human nasopharynx. *J. Anat.* **104**, 81–92.
- WEDDELL, G. (1945). The anatomy of cutaneous sensibility. *Br. med. Bull.* **3**, 167–172.
- WEDDELL, G., PALMER, E. & PALLIE, W. (1955). Nerve endings in mammalian skin. *Biol. Rev.* **30**, 159–195.
- WOOLLARD, H. H., WEDDELL, G. & HARPMAN, J. J. (1940). Observations on the neurohistological basis of cutaneous pain. *J. Anat.* **74**, 413–440.