THE PERIPHERAL CONNEXIONS BETWEEN THE LINGUAL AND HYPOGLOSSAL NERVES

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INTRODUCTION

The peripheral connexions between the lingual and hypoglossal nerves have merited special study for the following reasons.

(1) The accounts of these connexions in the current textbooks of human anatomy are at variance with some of the older works. Current descriptions are similar to that of Schäfer & Symington (1909), in which we find that beyond the point where the lingual nerve gives off its supply to the submandibular ganglion, 'one or two filaments descend over the fore-part of the hyoglossus muscle to join in loops with similar branches of the hypoglossal nerve'. On the other hand, Testut (1905) states that this connexion may be plexiform; and Poirier, Charpy & Cunéo (1908) illustrate a plexiform connexion on the hyoglossus muscle, and show in addition what appears to be an intramuscular lingual-hypoglossal linkage further forwards.

(2) Boyd (1941), in his study of the hypoglossal nerve in the rabbit, has noted 'some plexus formation' between branches of the lingual and hypoglossal nerves. We have not been able to find any other reference to peripheral lingual-hypoglossal connexions in lower mammals.

(3) The functional significance of the lingual-hypoglossal connexions does not appear to have been the subject of any previous investigation.

MATERIAL AND METHODS

Morphological

The peripheral parts of the lingual and hypoglossal nerves were dissected in forty human specimens obtained from twenty-five adult subjects. The animal material was drawn from bilateral dissections in pigs (12), cats (6), dogs (6) and rabbits (4).

Experimental

The normal tongue was studied in twelve young pigs ranging from birth to 3 months post-natal age. Fixation was carried out by ante-mortem perfusion with 10% formol saline. Tissue blocks were made and placed in 8% neutral formalin. The neurohistology of the tongue was examined by means of frozen sections cut at 50–75 μ in sagittal, coronal and horizontal planes, and stained by the diamine silver-ion technique (Garven & Gairns, 1952). Paraffin sections at 15 μ stained with haematoxylin and eosin, or by the Mallory method, were also examined in order to facilitate the orientation of the lingual muscle groups and the intralingual ganglia.

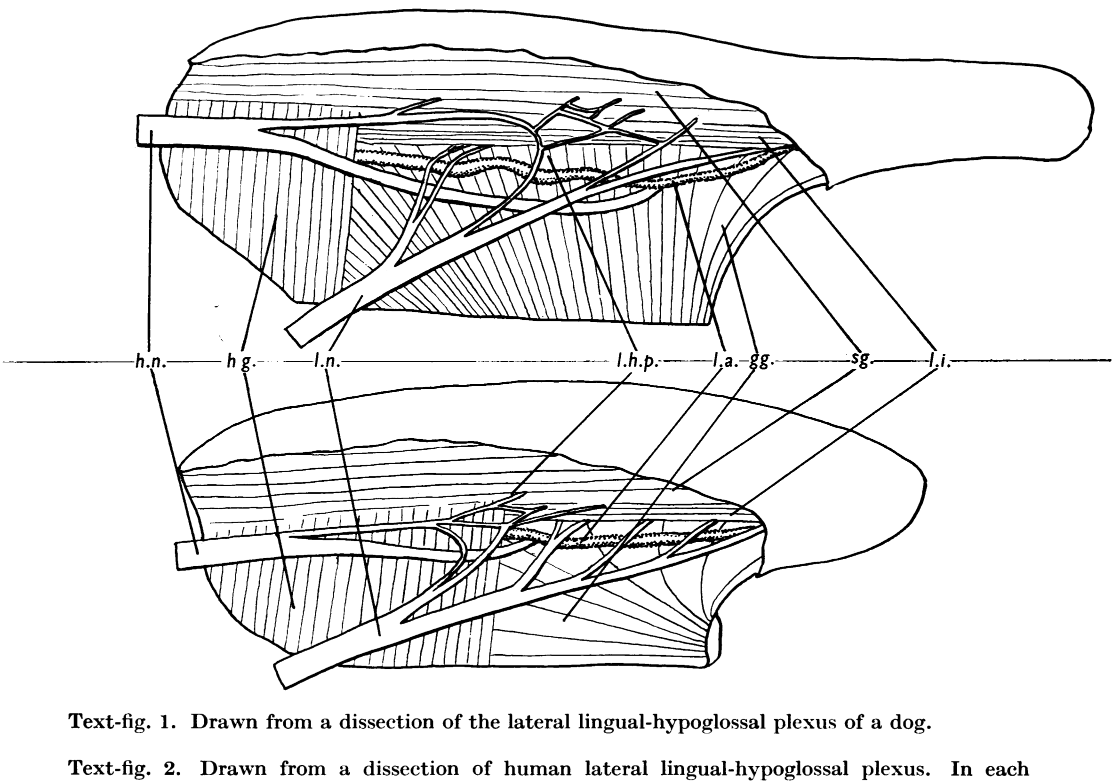
In ten of the twelve animals, the isolated hypoglossal trunk was divided into three segments which were embedded in paraffin. Serial longitudinal sections from each segment were cut at 15μ and stained with haematoxylin and eosin. A segment of the medulla at the level of the issuing hypoglossal roots was stained by the Bielschowsky block-silver technique, and serial sections at 10μ were taken in the transverse plane. This study was undertaken to investigate the existence of ganglion cells on the roots or trunk of the nerve.

Five animals were used for experiments; they ranged in age from 3 to 6 weeks. In three of them the hypoglossal nerve was divided unilaterally at the posterior border of the mylohyoid muscle; in a further pair the lingual nerve was cut at the side of the styloglossus. In each case the operation was carried out under Nembutal and ether anaesthesia, and a small segment of the nerve (approx. 2 mm.) was removed. The survival period for each animal was 4 weeks. Material from the tongues of the experimental animals was prepared by the diamine silver ion method as previously described.

OBSERVATIONS

(*a*) *Morphological*

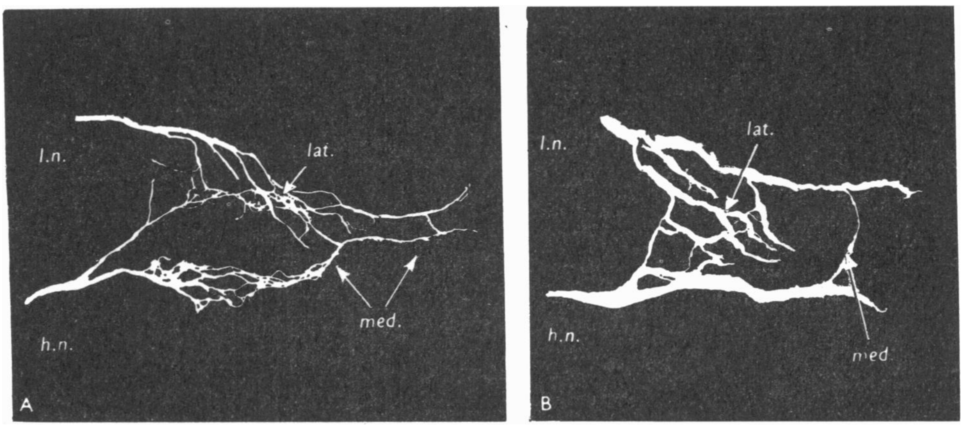
The comparative anatomy of the *lateral* lingual-hypoglossal connexions is illustrated by Text-fig. 1 (dog), and Text-fig. 2 (man). In each it is the lateral division of the



Text-fig. 1. Drawn from a dissection of the lateral lingual-hypoglossal plexus of a dog.

Text-fig. 2. Drawn from a dissection of human lateral lingual-hypoglossal plexus. In each specimen the hypoglossal trunk was raised and the lingual nerve turned down, to show the plexus. The nerve supply to the hyoglossus and genioglossus is not shown. *gg.*, genioglossus; *hg.*, hyoglossus; *h.n.*, hypoglossal nerve; *l.a.*, lingual artery; *l.h.p.*, lateral lingual-hypoglossal plexus; *l.i.*, longitudinalis inferior; *l.n.*, lingual nerve; *sg.*, styloglossus.

hypoglossal nerve which establishes connexion with branches of the lingual. In the lower animals examined the plexus so formed was found constantly, and lay either on the surface of the styloglossus muscle or (in the case of the cat and rabbit) embedded in its fibres. In man there is a marked forward extension of the hyoglossus muscle; only in our human material did we find that the major branches of the hypoglossal nerve to the posterior musculature of the tongue hooked round the anterior border of this muscle. The forward extension of the hyoglossus brings the human lateral lingual-hypoglossal connexion to lie on its outer surface. In all species studied the issuing fibres from this plexus were seen to enter the tongue lateral to the plane of entry of the remaining branches of the lingual nerve. The former enter the styloglossus or inferior longitudinal muscle, sometimes (in man) piercing the anterior fibres of the hyoglossus in their course; the latter turn upwards between the inferior longitudinal muscle and the genioglossus.

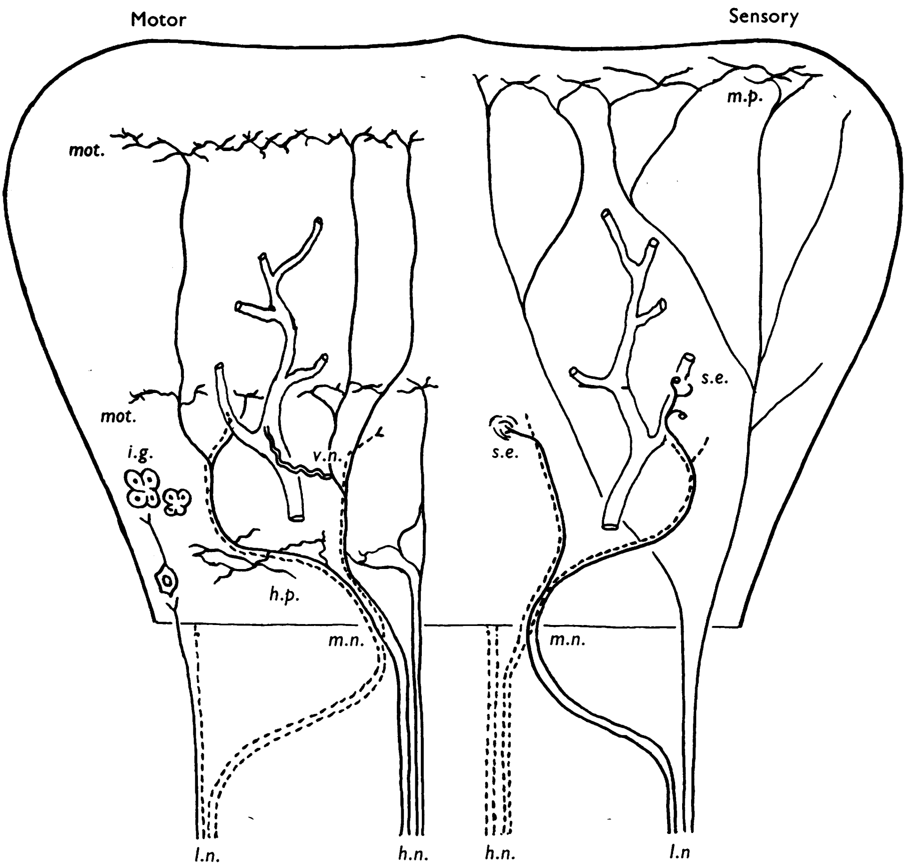


Text-fig. 3A. Photograph of the lingual-hypoglossal connexions from a pig. B, The same, from man. *h.n.*, hypoglossal nerve; *lat.*, lateral lingual-hypoglossal connexions; *l.n.*, lingual nerve; *med.*, medial lingual-hypoglossal connexions.

A lateral lingual-hypoglossal connexion was found in thirty-six dissections in man (90 %). Its simplest form was that of a Y-shaped junction between a lingual and hypoglossal branch; and microscopic examination of such a specimen, after clearing, reveals that the branches become intertwined to form a single trunk. This trunk emerges from the hypoglossal end of the link and gives a first impression of simple loop formation between lingual and hypoglossal trunks. This appears to be the explanation of the account by Schäfer & Symington (1909) already referred to. The connexions were single in twenty-seven dissections, double or triple in the remainder (Text-fig. 3B and Pl. 1).

The most complex form of lateral lingual-hypoglossal connexion was found in the adult pig (Text-fig. 3A). In this animal the issuing fibres enter the tongue along the whole length of the styloglossus and inferior longitudinal muscles beyond the hyoglossus. In the dog and cat the plexus is simpler and is formed by the union of the lateral division of the hypoglossal with one or two branches of the lingual nerve, the issuing bundles all entering the styloglossus.

A *medial* lingual-hypoglossal connexion was found in sixteen (40 %) of our human dissections, and was constantly present in the tongue of the dog, cat and pig. In the small tongue of the rabbit no such connexion could be demonstrated. This connexion is formed by the union of one or more branches of the lingual nerve with fibres of the medial division of the hypoglossal. In eleven human specimens the connexion was situated proximally, among the lateral fibres of the genioglossus.



Text-fig. 4. **Schematic representation of the pattern of the motor and sensory innervation of the anterior two-thirds of the tongue. For explanation see text.** ***h.n.*****, hypoglossal nerve;** ***l.n.*****, lingual nerve;** ***h.p.*****, hypoglossal plexus;** ***i.g.*****, intralingual gland;** ***m.n.*****, mixed nerve;** ***mot.*****, motor plexus;** ***m.p.*****, mucosal plexus;** ***s.e.*****, sensory ending;** ***v.n.*****, vasomotor nerves.**

In eight it was distal and took place near the tip of the tongue (Text-fig. 3B); from this loop of communication fine twigs entered the intrinsic musculature. (In three cases proximal and distal connexions were found in the same specimen.) In the dog and pig both proximal and distal connexions were to be found as just described; while in the cat there was a simple conjunction between the most anterior branch of the lingual nerve and the medial division of the hypoglossal, the two forming a single trunk which entered the genioglossus.

(b) Experimental

Normal neurohistology. Branches of the medial and lateral divisions of the hypoglossal nerve pierce the musculature of the pig's tongue and divide into smaller bundles which form a plexus extending throughout the tongue from back to front. This plexus is dense among the upper fibres of the genioglossus (Pl. 2, fig. 1), but loose and open elsewhere. The following fibres emerge from the plexus: (1) Bundles of axons which form fine motor plexuses in relation to the individual tongue muscles. (2) Fine fibres of vasomotor type which run either singly or in groups to the blood vessels. These fibres unite to form a single, flattened band or 'taenia nervosa' which lies on the outer surface of the tunica media. (3) Myelinated fibres which pass to the adventitia of the small and medium arteries, where they form a rich network of coarse and fine fibres (Pl. 2, fig. 3). Nerve endings, usually in the form of fine perinuclear hooks or coils were frequently observed in the adventitia (Pl. 2, fig. 4). (4) Myelinated fibres which form sensory endings in the intramuscular connective tissue, particularly where this is loose in texture and rich in fat cells. The fibres forming such endings issue singly from the bundles of the hypoglossal plexus, and terminate in a coil or a bifurcation within a thin mass of connective tissue which frequently shows a pattern of concentric lamination (Pl. 2, fig. 2). Occasionally, the endings take the form of a bulb-like dilatation or a perinuclear loop.

Our examination of the hypoglossal nerve included both its roots and its trunk. No sensory ganglia or isolated sensory cells were observed. Text-fig. 4 is a diagrammatic illustration of the neurohistology of the pig's tongue. It is derived from the normal pattern recorded above and from the experimental observations now to be described. Branches of the lingual nerve run upwards through the musculature. These branches can as a rule be distinguished from the bundles of the hypoglossal plexus by their well-defined course towards the mucosa, and by the fact that arborization only commences in the submucosal region.

Operative findings

Section of hypoglossal nerve. Table 1 summarizes the results of hypoglossal nerve section; these results were similar in all three experiments.

Table 1. *Results of hypoglossal nerve section*

Region	Degeneration
Trunk distal to section	Complete
Intramuscular plexus	Partial
Motor plexuses and motor endings	Complete
Sympathetic vasomotor fibres	Partial
Fibres to adventitia of vessels	None
Fibres ending in connective tissue	None

On the operated side of the tongue there was complete degeneration of the motor plexuses and endings and a general proliferation of fibroblasts throughout the intramuscular connective tissue. The characteristic pattern of the hypoglossal plexus was changed into that of a number of isolated bundles. These bundles, which consisted of a varying number of normal fibres intermingled with cellular tissue and fragments of degenerated axons, were considered to be mixed nerve branches derived from the lingual-hypoglossal plexuses. Occasionally, but very rarely, normal fibres were seen to enter them from unaffected branches of the lingual nerve (Pl. 3, fig. 9). From the mixed nerve bundles we were able to trace normal fibres to the adventitia of the vessels and the intramuscular connective tissue. Pl. 2, fig. 5 shows a longitudinally cut nerve bundle in the genioglossus, 28 days after section of the hypoglossal nerve. Although the greater number of the fibres in the sheath are degenerated, some normal fibres can still be seen; several of these latter fibres leave the sheath to end in the adjacent connective tissue. One of these endings is enlarged in Pl. 2, fig. 6. Pl. 3, fig. 13 shows a second bundle in the intrinsic musculature of a post-operative tongue. A normal fibre can be seen to leave it and pass to meet another one at right angles. The two run together round an arterial wall, one terminating in an adventitial perinuclear coil; the other was traced to a fine adventitial ending some distance away.

We could find no evidence that the adventitia of the blood vessels was supplied with fibres from purely lingual nerve bundles. Post-ganglionic nerve fibres travelling in the branches of the lingual nerve were noted in the vicinity of some small arterioles. This aspect of vascular innervation must be the subject of a separate study.

Sagittal sections of the tongue at the point of entry of the first order branches of the lingual artery revealed a few fine fibre bundles of vasomotor type along their walls; such fibres, however, could not be found along arterial branches of higher order.

Section of lingual nerve. Table 2 summarizes the results of lingual nerve section.

Table 2. *Results of lingual nerve section*

Region	Degeneration
Trunk distal to section	Complete
Sensory branches to epithelium	Complete
Fibres to vascular adventitia and intramuscular connective tissue	Complete
Pre-ganglionic parasympathetic	Complete
Post-ganglionic parasympathetic	None

The results of lingual nerve section were in general the converse of those found after section of the hypoglossal nerve.

In the post-operative specimens we found complete degeneration of the lingual nerve bundles passing to the mucous membrane. Both the connective tissue endings and the plexuses and endings in the vascular adventitia of the anterior two-thirds of the tongue were now absent. The vascular nerves remaining were as follows: (*a*) the normal supply of vasomotor fibres to the whole arterial tree (Pl. 3, fig. 12); (*b*) very occasional fibres proceeding from multipolar-celled ganglia to the small arterioles (these have been referred to earlier as the subject of a separate study); and (*c*) small nerve fibres on the walls of some of the vessels in the mucous membrane.

The presence of mixed nerve bundles in the intramuscular plexus of the hypoglossal nerve, demonstrated by hypoglossal nerve section, was confirmed by section of the lingual nerve (Pl. 3, fig. 11). From our observations it appeared that approximately one-fourth of the nerve bundles of this plexus contained varying proportions of motor and sensory nerve fibres.

The ganglia and post-ganglionic fibres of the parasympathetic component to the lingual glands were not visibly affected by nerve section. Many of the nerve bundles passing to the lingual glands presented an entirely normal appearance; in others disintegrating remnants of the preganglionic element predominated.

DISCUSSION

The gross anatomy

In man, a lateral and a medial division of the hypoglossal nerve are not usually described. In his study of the human tongue, Abd-el-Malek (1939) refers to two divisions of the nerve, stating that 'the smaller, which we may call the lateral division, runs in between hyoglossus, styloglossus and inferior longitudinal muscles supplying them with several fibres.' There is no reference to the lingual nerve, so that the branch he refers to appears to be different from the one described in this work. In lower mammals the lateral division of the hypoglossal nerve is relatively much larger than in man. However, what we have asserted to be the human counterpart conforms with it in all other respects, save the following: in man the lateral division cannot be said to run lateral to the lingual nerve as it links up with the most posterior branch or branches of the lingual (Text-fig. 2). Toldt (1926) illustrates a large branch of the hypoglossal which gives off a twig to form a loop with the first branch of the lingual, and then runs forwards lateral to its remaining branches. So far as it goes, this is in accord with our description.

The disposition of the fibres derived from the lateral and medial lingual-hypoglossal connexions in the species examined, suggests that lingual nerve bundles are distributed in the territory of the hypoglossal. Thus, reference to the anatomical findings shows (*a*) that in the case of the lateral plexus the ultimate branches enter the musculature lateral to the remaining branches of the lingual nerve, in line with the earlier twigs from the lateral division of the hypoglossal (to the styloglossus); and (*b*) that the medial division is generally joined by a branch of the lingual nerve which leaves its fellows and travels forwards and medially to meet it.

The neurohistology

The sensory component of the hypoglossal nerve. Tarkhan (1936) reported the presence of a sensory ganglion on the hypoglossal trunk in the rabbit. This finding was not confirmed by the degenerative experiments of Carleton (1938) or by Boyd's (1941) observational study of the hypoglossal nerve in embryo and adult rabbits. Neither of these workers found any evidence of sensory ganglia or scattered sensory cells on the course of the nerve. Our examinations of the hypoglossal nerve in the pig have given results which are in conformity with those of the two latter workers.

Weddell, Harpman, Lambley & Young (1940) state that division of the hypoglossal nerve at the root of the tongue in the rabbit is followed by degeneration of all nerve fibres to its musculature and blood vessels, whereas section of the nerve at the base of the brain leaves the vascular nerves intact. Carleton (1938) found that some fine nerve fibres in relation to the blood vessels persisted after section of the hypoglossal a short distance from the base of the skull. It is not clear, however, whether the section was distal or proximal to the connexion of the superior cervical sympathetic ganglion with the hypoglossal trunk.

Our observations following section of the hypoglossal nerve at the root of the tongue are not in agreement with those of Weddell *et al.* (1940) since, as we have shown, healthy fibres are found in the intramuscular connective tissue and on the vascular walls. This discrepancy may be due to a species difference in the distribution of sensory fibres in the tongue muscles.

The interpretations of electro-physiological experiments in relation to the sensory fibres in the hypoglossal nerve have produced conflicting opinions. Those concerned with stimulation of the central end of the divided nerve (Downman, 1939; Tarkhan & Abd-el-Naga, 1947) are not germane to the present paper. Barron (1936) was unable to obtain any record from the hypoglossal trunk on stretching, burning or deforming the tongue of anaesthetized or decerebrate cats, rats and rabbits. Cooper (1954), on the other hand, found electro-physiological evidence of a sensory component in the medial division of the hypoglossal nerve beyond its branches to the genioglossus in the cat. Her finding appears to be in conformity with the anatomical pattern of communication between the lingual and hypoglossal nerves that we have demonstrated.

The intramuscular connective tissue endings. Muscle spindles in the intrinsic tongue muscles of the rabbit were reported by Tarkhan (1936). Carleton (1938) was, however, unable to confirm this finding in the same species. Using intravitam methylene-blue technique, Weddell *et al.* (1940) found no proprioceptive endings of standard type in the intrinsic muscles of the rat's tongue. They observed some sensory endings in the genioglossus near its bony attachment, but the origin of the nerve fibres supplying these endings were not determined. Boyd (1941) denies the presence of muscle spindles in the intrinsic tongue muscles of the rabbit, but is in agreement with Weddell *et al.* (1940) with regard to certain atypical sensory endings in the extrinsic musculature. Cooper (1953) has shown typical muscle spindles in the intrinsic tongue muscles of man and rhesus monkey, and states that spindles are absent in the lingual muscles of cat and sheep.

Our studies of pig material have shown no evidence of proprioceptive endings in the intrinsic or extrinsic muscles. The possibility that such endings may be present in the genioglossus cannot be entirely excluded, as the large size of the muscle in this animal makes complete examination difficult.

Intramuscular connective tissue endings of the type we are reporting do not appear to have been referred to by other workers. Since there are apparently no muscle spindles in the lingual muscles of the pig, it may well be that these connective tissue endings mediate proprioception in the tongue of this animal. The possibility of the myaesthetic role of these bodies becomes more apparent when one recalls their absence in the pig's ocular muscles, where muscle spindles are abundant (Law & FitzGerald, 1956).

The sensory innervation of the blood vessels. The pattern of vascular innervation we have described in the pig's tongue is essentially similar to what has been described for other parts of the body, such as skin (Woollard, 1926); skeletal muscle (Hinsey, 1929); ear (Woollard, Weddell & Harpman, 1940); and stomach wall (Millen, 1948).

With regard to the manner of delivery of sensory vascular fibres, both our observational and our experimental results agree with those of previous workers. In rabbits, Hinsey (1929) found that the adventitial nerve plexus in the vessels of skeletal muscle was unaffected by ventral root section and sympathetic neurectomy. Woollard *et al.* (1940) state that normal myelinated fibres are found in the vessels of rabbit's ear following cervical sympathectomy, and Bowden & Mahran (1956) describe intact perivascular and adventitial fibres in the quadratus labii superioris of the rabbit after division of the facial nerve. The findings of the latter workers are like our own; the perivascular fibres were traced in their material to the regional sensory nerve (the infra-orbital) via the regional branches of the motor nerve (the facial). The collective evidence, therefore, shows that such afferent fibres are delivered to the vessels of the muscles in 'mixed' motor nerve branches; in the case of non-muscular areas, however, the vascular afferents travel with the somatic afferents.

It would seem then that the lingual nerve is a proprioceptive pathway for both extrinsic and intrinsic muscles of the anterior part of the tongue. The proprioceptive function of the mandibular nerve in respect of the masticatory muscles was demonstrated by Allen (1919); and Cooper, Daniel & Whitteridge (1955) have shown that a similar office is performed by the ophthalmic nerve for the muscles of the orbit. Thus, it appears that the first and third divisions of the trigeminal nerve have been demonstrated effectively as the proprioceptive trunks for three of the muscle groups of the splanchnocranium.

SUMMARY

1. The anatomy of the peripheral connexions between the lingual nerve and the lateral and medial divisions of the hypoglossal is described in man and some lower mammals.

2. The topographical findings show that the loops of communication commonly described between the lingual and hypoglossal trunks of man form a lateral lingual-hypoglossal plexus. The contribution or contributions to this plexus from the hypoglossal nerve are homologous with the lateral division of this nerve in lower mammals.

3. The neural pattern in the musculature of the normal tongue is described in the pig. Particular reference is made to certain fibres in the plexus of the hypoglossal nerve which leave to end in the intramuscular connective tissue and in the adventitia of blood vessels.

4. The results of (*a*) hypoglossal nerve section, and (*b*) lingual nerve section are recorded. It is shown that adventititial and connective tissue fibres are unaffected by section of the hypoglossal nerve and that they degenerate after the lingual nerve has been divided.

5. It is concluded that sensori-motor branches arise from the lingual-hypoglossal plexuses, and supply sensory fibres to the intramuscular connective tissue and vascular walls in the anterior two-thirds of the tongue.

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EXPLANATION OF PLATES

Plate 1

Photograph of the lateral lingual-hypoglossal plexus from a human dissection. *h.n.*, hypoglossal nerve; *l.a.*, lingual artery; *l.h.p.*, lateral lingual-hypoglossal plexus; *l.i.*, longitudinalis inferior; *l.n.*, lingual nerve; *sg.*, styloglossus.

Figs. 1–13 are photomicrographs of material taken from pig's tongue and stained by the diammine silver-ion technique.

Plate 2

Fig. 1. Normal tongue. Sagittal section through the genioglossus and transversalis muscle showing part of the plexus of the hypoglossal nerve.

Fig. 2. Normal tongue. Nerve fibre ending in the connective tissue between the bundles of the longitudinalis superior. Note concentric lamination of the connective tissue around the ending.

Fig. 3. Normal tongue. Nerve plexus in adventitial coat of arterial wall.

Fig. 4. Normal tongue. Coarse and fine fibres in an adventitial plexus.

Fig. 5. Hypoglossal nerve section. Mixed nerve bundle in genioglossus muscle of post-operative tongue. Note mingling of normal and degenerated fibres. Single normal fibres are seen leaving the bundle to enter the adjacent connective tissue. One of these fibres (arrow) is enlarged in Fig. 6.

Fig. 6. Enlargement of part of Fig. 5. There is a connective tissue lamina round the nerve ending.

Fig. 7. Hypoglossal nerve section. Forked nerve-ending in intramuscular connective tissue. A degenerated nerve bundle is seen below it.

Plate 3

Fig. 8. Hypoglossal nerve section. Normal perivascular nerves (arrows) to an artery near the dorsum.

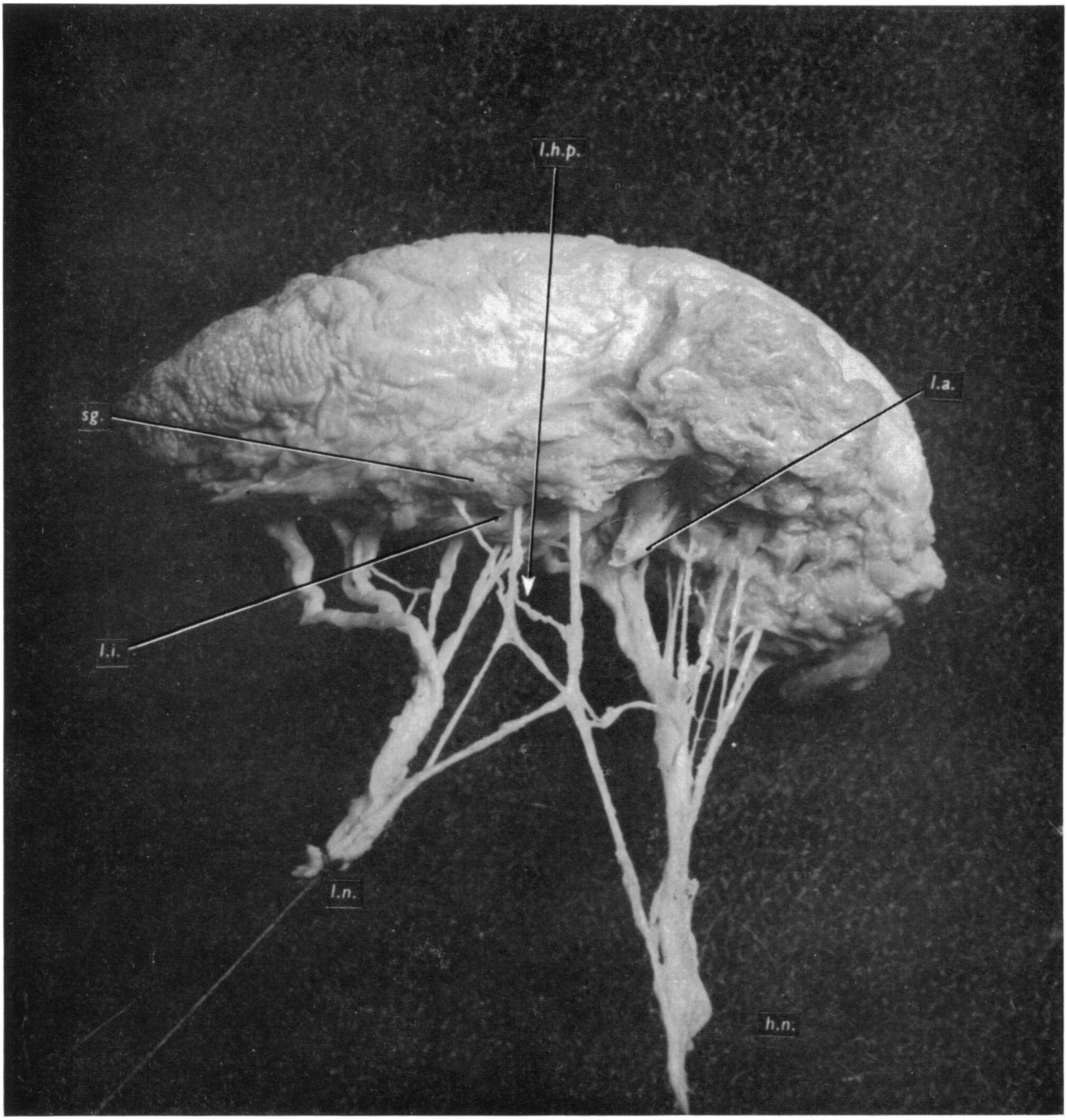
Fig. 9. Hypoglossal nerve section. Sagittal section through the intrinsic muscles of the tongue. A large mixed bundle is seen at the bottom of the picture. Two normal lingual nerve bundles are seen in the centre of the field. From the left-hand lingual bundle a normal fibre is passing to a small mixed bundle in the right upper corner.

Fig. 10. Hypoglossal nerve section. A mixed bundle from which a normal fibre is distributed to the adventitia of a small artery.

Fig. 11. Lingual nerve section. A mixed nerve bundle in the genioglossus muscle of the post-operative tongue.

Fig. 12. Lingual nerve section. High-power photograph of fine vasoconstrictor fibres in arterial wall.

Fig. 13. Hypoglossal nerve section. Normal nerve fibre (horizontal arrow) leaving a mixed bundle to join a second fibre (vertical arrow) near a small artery. The two fibres run round the vessel wall, one terminating in a coil (x) in the vascular adventitia.



FITZGERALD AND LAW—PERIPHERAL CONNEXIONS BETWEEN LINGUAL AND HYPOGLOSSAL NERVES

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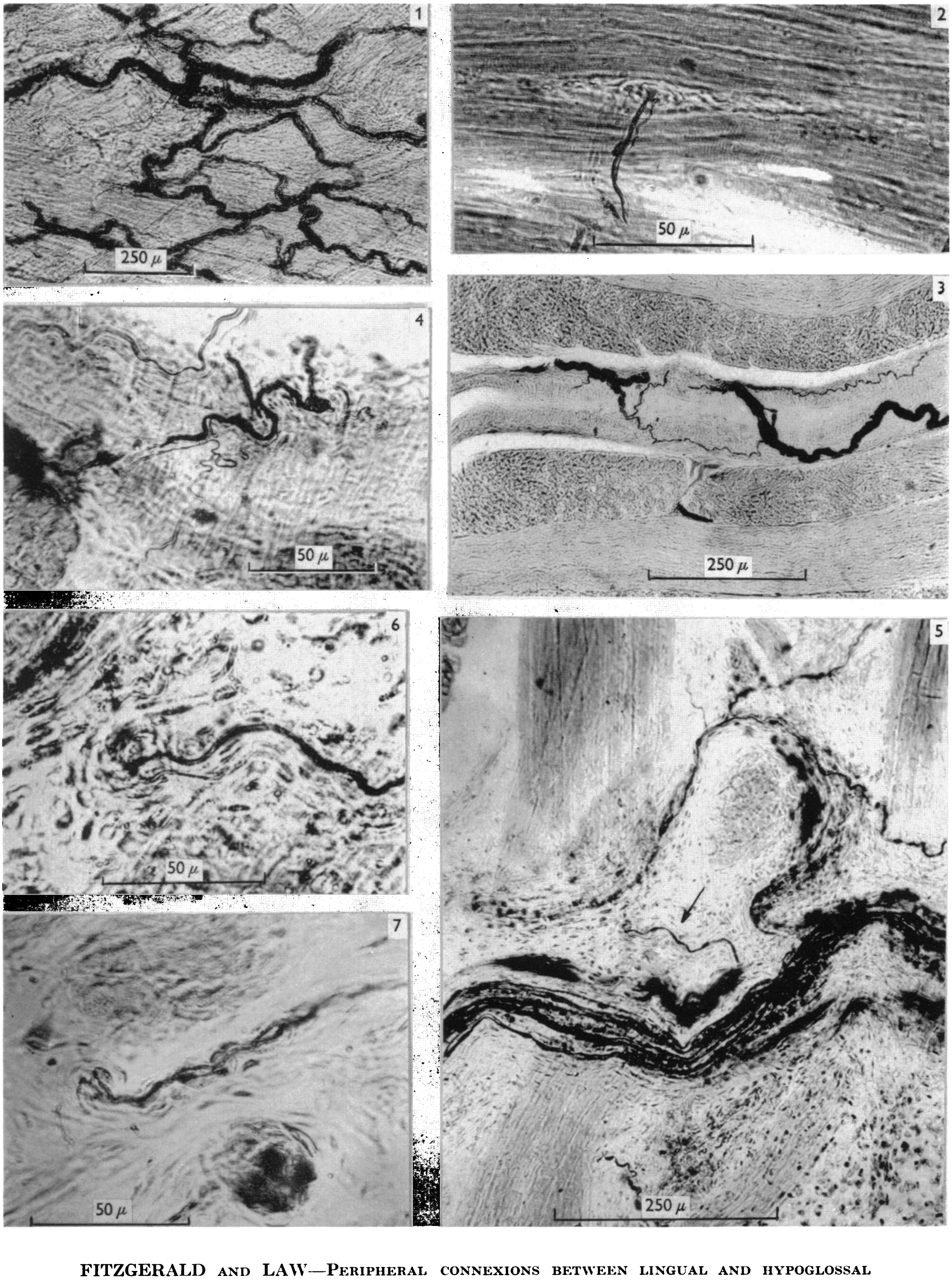

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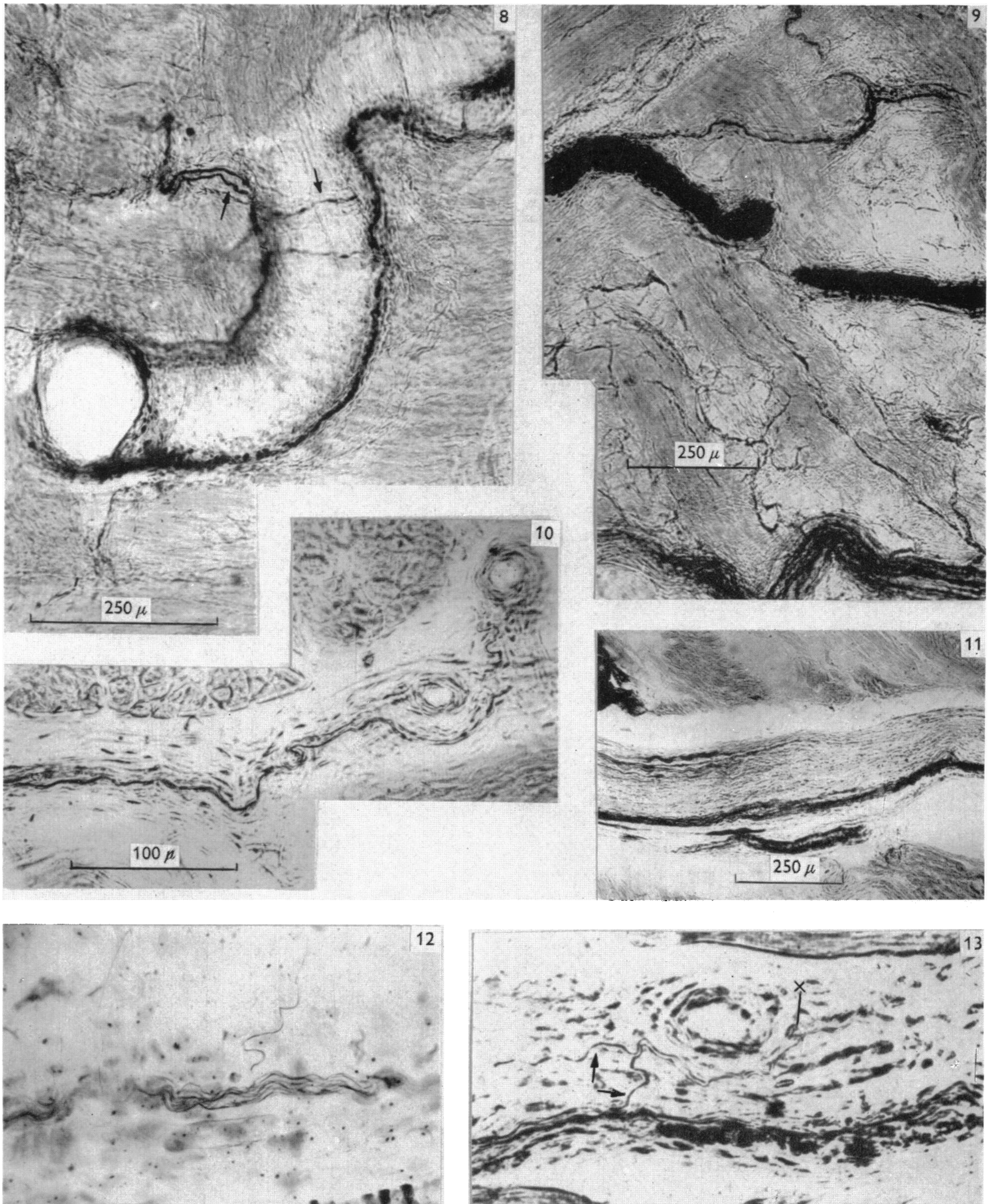

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