Innervation especially Sensory Innervation of Dog Tongue

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Many histological studies\(^1\),\(^2\),\(^3\) on the innervation of mammalian tongues have been reported and praiseworthy results achieved hitherto, but much seems yet left unexplored, and in particular, many questions are still waiting solution in connection with dog tongue. Recently, much light has been thrown on the subject of innervation of human tongue by the minute studies by Kumagawa,\(^4\) Nakayama,\(^5\) Inazawa\(^6\) and Ohgaki\(^7\) of this laboratory. So, I took the tongues of dog as my material, and through a thoroughgoing histological study on its innervation, especially sensory innervation undertook to elucidate its biological meaning, in comparison with the innervation of adult human tongue.

The materials were taken from fresh adult dog tongues, which were fixed for a long time in 10\% neutral formol, cut into 40\(\mu\) frontal frozen sections, and stained with Seto’s silver method in use in this laboratory. The series of beautiful stained preparations I subjected to a minute microscopic scrutiny and succeeded in arriving at many new informations as described in the following.

Individual Views

As is well known, the motor nerves for the tongue come from n. hypoglossus, while the sensory nerves from n. lingualis of n. mandibularis of n. trigeminus, n. glossopharyngicus as well as chorda tympani of n. intermedius and rr. pharyngici of n. vagus. The vegetative nerves, especially sympathetic nerves come from ganglion cervicale craniale. These nerve bundles enter from the outer side of the radix linguæ into the tongue muscles, and gradually dividing into smaller bundles, run to the periphery, to pass into crude nerve plexus. In the course, they contain the undermentioned multipolar nerve cell groups. Thick medullated motor fibres all end in the striated muscle fibres.

The small nerve bundles entering the subepithelial connective tissue...
through the muscle layer consist of thick medullated sensory and non-
medullated vegetative fibres, and pass into plexus, which is developed
far lower than in human tongue. Though in the base of the papillae
foliatae and circumvallatae conspicuous basal plexus are formed, other-
wise, almost nothing that may be called as plexus could be found in for-
mation. There are besides such vegetative fibres, which, running along
the blood vessels, form so-called vessel wall plexus, as is the case in human
tongue. They come into frequent anastomosis with the non-medullated
fibres in the above mentioned nerves.

1. Innervation of dog tongue muscles

The terminal mode of motor fibres for the tongue muscle in dog is
generally speaking similar to that of human tongue (Kumagawa). So,
the medullated stem fibres, as they approach the terminal area, in most
cases without losing the myelin, divide into 2 or 3 branches, then lose
the myelin and pass into very minute 2 to 5 terminal branches, each of
which terminates sharply or with a fibrillar plate or a small ring in minute-
ly granulated motor end-plate containing numerous round special nuclei
(Fig. 1).

About the existence of Boeke's so-called accessory fibres of sympathe-
cic nature, I am very much in doubt, as were Cajal, Hirano and Ku-
magawa, for I have found not rarely the existence of minute fibres dividing
from motor nerve fibres to end freely in the motor end-plate, and sympathe-
cic fibres terminate never freely.

As Nakayama proved the existence of rather well-developed muscle
spindles in human tongue, I made a strenuous research for such formation
in dog tongue but in vain. However, as Hatano reports existence of
muscle spindles in the foremost part of dog tongue, it may be that a very
limited formation of such spindles is possible.

2. Distribution of vegetative nerves in dog tongue

I frequently found existence of groups of 2 to 10 nerve cells in or
near the small nerve bundles penetrating the tongue muscles. These
cells are generally impervious to silver impregnation and also the nerve
processes stain badly, but whenever the silver impregnation is well executed,
the multipolarity of the nerve cells is proved clearly, and there is no doubt
that they are of sympathetic nature (Fig. 2). Nerve cells are also observed
accompanying the small nerves running between the lobules of serous
glands in the deeper layer of papillae foliatae and circumvallatae. These
ganglion cells as well as the Remak's hemi-ganglion cells in the basal
plexus of the above two kinds of papillae and the nerve cells sporadically
found in the tela submucosa should belong to the sympathetic system
mentioned above, according to my views, which are in concurrence in the views of Nakayama and Inazawa on human tongue. In short, in these cells, especially the development of nerve processes is extremely bad, somewhat unlike those in the common sympathetic ganglia, and as this fact shows the degenerated character of these cells, they are accordingly deemed as inferior in their functional efficiency.

The termination of the vegetative fibres running in the tongue is always represented by the terminalreticulum (Stohr), either in gland parenchyma, in muscle layer or in subepithelial connective tissue, as is the case with human counterparts. This terminalreticulum stands in tactile supply for all controlled cells, including gland cells, and never penetrates the cell bodies.

3. Sensory supply of dog tongue

The sensory terminations found in the dog tongue are mainly formed in the mucous membrane. The development of the sensory fibres is incomparably much less than in human tongue. That is, at the base of foliate and circumvallate papillae, the development of basal plexus is rather good, but otherwise, the plexus formation in tela submucosa and lamina propria is very poor and the sensory fibres in it are very limited in quantity.

Now, the sensory supply of all kinds of papillae is described in detail in each of following chapters, and I must dwell shortly therein also upon the fine structure of every papilla, since these papillae show various peculiar constructions rather dissimilar to the human tongue papillae, and this fact affects closely the sensory innervation.
Filiform papillae. The filiform papillae in dog are very different from those in human tongue. They are incomparably smaller in scale, generally of short cylindrical form having only a few secondary papillae, and though the epithelium is cornified, it does not show such a strong corneous plate formation as seen in human tongue. These are rather large in the foremost part of the tongue, but gradually diminish in size as the hinder part is approached. Thus, the filiform papillae in dog are very weak in development and the sensory terminations are correspondingly backward in development (Fig. 3).

The sensory fibres running into the connective tissue trunk of the filiform papillae consist of thick and thin medullated fibres, which are gathered in 2 or 3 fibres, in rarer cases, in 5 or 6, and in accompaniment of fine vegetative fibres, run into the trunk, often as far as the secondary papillae.

As terminal forms in the filiform papillae, simple unbranched terminations consisting of sensory fibres ending sharply without any branching after lost of the myelin (Fig. 3) and simple branched terminations consisting of 2 or 3 simple branches (Fig. 3 and Fig. 4) may be mentioned.

![Fig. 3](image1)
![Fig. 4](image2)

Fig. 3. An unbranched and a branched termination formed in a filiform papilla in dog tongue. Same staining, X 200, reduced to 2/5.

Fig. 4. Branched termination divided into 3 branches found in a filiform papilla. Dog tongue. Same staining, X 500, reduced to 2/5.

The stem fibres are generally medium sized or thin, but sometimes thick fibres also can be seen, the latter very often showing peculiar change in size and winding course (Fig. 5). No intraepithelial fibres, into which the terminations further pass, are seen running, in all probability because the epithelium is cornified in nature.

Next, the remarkable fact to be mentioned is that there is no where observed in the filiform papillae in dog any complex formed corpuscal
terminations, such as glomerular and genital nerve bodies. When we recollect the view expressed by Seto to the effect that the complex corpuscular terminations are of extremely fine and delicate sensory nature, that is to say, they are the terminal seats of higher sense apperception, it is an interesting fact that there are no such highly evolved terminal apparatus in filiform papillae in dog as seen in human specimen.

**Fungiform papillae.** Of the fungiform papillae in dog, those in the foremost part of the tongue are comparatively small in size, but those in the hinder part are larger, having conspicuous secondary papillae and containing comparatively numerous taste buds in the covering epithelium.

The innervation of these papillae is very poor in the foremost part, just like in the filiform papillae, but shows somewhat more complexity as the hinder part is approached. For example, plexus resembling the basal plexus found in the circumvallate papillae, but far lower in development than this, can be frequently observed (Fig. 6).

This plexus is composed of rather numerous thin and thick medullated sensory and fine non-medullated fibres. The sensory fibres always run to the periphery of the papillae, to pass into sharply ending simple unbranched or simple branched terminations dividing into 2 or 4 branches. The latter sometimes are represented as plexus-like terminations showing irregular winding arrangement, as shown in Fig. 7.

In the fungiform papillae also, as in the filiform papillae, no corpuscular terminations are found existing, as are so conspicuously formed in those in human tongue. This fact also suggests that the sensory termi-
nations in dog tongue are much lower in functional nature than those in human tongue.

In the fungiform papillae, intraepithelial fibres were clearly observed, which was not the case with filiform papillae. This is apparently due to the fact that the surface of the epithelium here is not cornified, but covered with a thin corneous plate. Their development is, however, very weak, the majority being without any branches. The development of the sensory fibres for the taste buds is also very weak in comparison with those in circumvallate papillae described hereunder. The sensory fibres running toward the taste buds are not at all numerous, sometimes being absent all together. But in rarer cases, fibres are sent further out into or around the taste buds as so-called intra- and extragemmal fibres. These, however, are always of the simplest kind, generally ending unbranched (Fig. 6 and Fig. 7).

![Fig. 7. Unbranched and branched terminations in a fungiform papilla in dog tongue. i intraepithelial fibre; t taste bud. Same staining, X 500, reduced to 2/5.](image)

**Foliate and circumvallate papillae.** The foliate papillae in dog show a specially typical development in comparison with those in other mammals. Their epithelium facing the surrounding groove as well as that toward the mouth cavity contain numerous taste buds.

The circumvallate papillae are much fewer in number than those in man, numbering in most cases only 4, and in rare cases, 6 in total. They are considerably different from human ones also microscopically. As shown clearly in Fig. 8, the epithelium facing the mouth cavity, as well as that facing the groove around it, are equally thin, both being provided with taste buds, showing the same arrangement as in human embryo (Nakayama). On the top surface, 1 or 2 grooves of considerable depth are engraved. The epithelium lining these grooves are much thicker than the taste bud epithelium, and no taste buds are seen therein. While the wall epithelium surrounding the circumvallate papillae in man is thin and contains many taste buds, by dog the formation of taste buds therein is very limited, though the epithelium shows the nature of taste bud epithelium yet, so much so that some investigators deny existence of
taste buds in it altogether.

Both the foliate and circumvallate papillae show peculiarity in fine structure of mucous membrane, as shown above, but the minute structure of the deeper layers is not much different from that in man. Under the tunica submucosa, there is striated muscle layers containing strongly developed serous glands, the ducts of which generally open into the basal part of the grooves.

The distribution of the sensory nerve fibres in these two kinds of papillae is as follows. At the base of the papillae, as in man, basal plexus provided with Remak’s hemi-ganglion cells is observed, as shown in Fig. 8. The nerve elements therein are composed of thick medullated sensory and finer non-medullated vegetative fibres. The development of the former is considerably strong, not much behind that in man, while that of the latter is somewhat poorer.

The Remak’s hemi-ganglion cells are multipolar cells far smaller than the common sympathetic cells, as described above, and are of sympathetic nature without doubt. The medullated fibres penetrating into the papillae from the basal plexus are of course sensory fibres, but some investigators assume that the fine non-medullated fibres also are sensory, especially representing gustatory fibres. However, I look upon these fine fibres as of vegetative nature, as is the case in human tongue (Nakayama), seeing that they become preterminal fibres, after sundry mutual nerve anastomosis, finally to pass into vegetative terminal reticulum.

The sensory fibres in foliate and circumvallate papillae are in far better development than in the filiform, and even fungiform papillae described above. They all run out of the basal plexus into the papillar trunk, and spread out radially toward the periphery to end mainly directly beneath the epithelium in terminations of various forms.

Of the terminal formations, simple unbranched terminations may be mentioned first. These are found only extremely rarely in these kinds of papillae. Most of the terminations found in these two kinds of papillae are represented by branched terminations showing various forms. They are divided further into simple and complex branched terminations, the latter again into arborized terminations or plexus-like terminations, according to the mode of running course of the branches.

For example, the termination seen at the center of Fig. 9 shows a typical arborized one composed of many branches formed under the epithelium on the top surface of a foliate papilla. In this kind of terminations the fibres show little change in size, tapering off gradually to end mainly sharply. Fig. 10 shows a comparatively complex plexus-like termination formed directly beneath the epithelium of a foliate papilla. In this formation 2–3 stem fibres partake, and the terminal fibres show
marked change of size in places. Also the existence of undetermined terminations showing remarkable change in size is frequently observed closely beneath the epithelium. Besides, in these two kinds of papillae, intraepithelial fibres running into the epithelium are found comparatively numerously, though they are mostly of simple unbranched nature.

As described above, in the foliate and circumvallate papillae there are seen many taste buds, the gustatory fibres for which are rather remarkable in development, as detailed hereunder, though not so well-developed as in man.

Also in dog, as in man, the development of gustatory nerve fibres for the taste buds in the circumvallate papillae seems to be somewhat inferior than that in the foliate papillae. In both papillae, it is almost impossible to find such typical glomerular terminations formed directly under the taste buds, as frequently seen in those in man. But under the taste buds of foliate papillae, some smaller sized terminations, that may well be called quasi-glomerular bodies, can be observed, as shown in Fig. 11. On the other hand, under the taste buds of the circumvallate papillae, such complex, quasi-corpuscular terminations are never found. However, it is similar to the case in man, that very simple loop-like terminations (Fig. 12), plexus-like terminations and other kinds of simple branched and unbranched terminations are formed under the taste buds of these both kinds of papillae.

Now, for the taste buds themselves, many intraepithelial fibres originated in all of the terminations formed under the taste buds described
Fig. 10. Plexus-like termination formed directly under the epithelium of a foliate papilla in dog tongue. An intraepithelial fibre is seen at the extreme right. Same staining, X 500, reduced to 2/5.

Fig. 11. Quasi-glomerular termination formed directly under a taste bud in a foliate papilla. Dog tongue. Same staining, X 1000, reduced to 2/5.

Fig. 12. Simple loop-like termination found directly under a taste bud in a circumvallate papilla. Dog tongue. Same staining, X 1000, reduced to 2/5.

Fig. 13. Some intragemmal fibres terminating sharply in a taste bud in a foliate papilla. Dog tongue. Same staining, X 1000, reduced to 2/5.

above very often may be found running into or around the taste buds (intra- or extragemmal fibres), as shown in Fig. 12 and Fig. 13. But as
these fibres generally end unbranched, it may be understood that the
development is inferior to that of human counterparts. These intraepi-
thelial fibres, as common intraepithelial fibres, take their running course
always inter- and intracellularly, and going up, end sharply, or some-
times bluntly, only in very rare case, forming knob-like or lamellar bodies
formed by fibrillar expansion, as seen in human tongue. This fact also
suggests the lower development of the gustatory fibres in dog than in
man.

So much about the taste buds closely connected with the gustatory
nerve fibres. There are furthermore, very numerous taste buds which
receive no such sensory supply at all. As stated under the fungiform
papillae, such taste buds without sensory innervation are deemed to be
more or less degenerated entities, without adequate functions as taste
buds.

Summary

There is no essential histological difference between the motor end
plates in the tongue of dog and that of man. In the former, as well in
the latter, the Bocke’s accessory fibres are not of sympathetic but of motor
nature. In the canine tongue, few if any muscle spindles are found.

The nerve cells found in many places on the nerve bundles running
through the tongue muscles and gland parenchyma, the Remak’s hemi-
ganglion cells in the basal plexus in the foliate and cirumvallate papillae
and the sporadically occurring nerve cells in tela sambucosa are all small
and degenerative, but are multipolar and must be of sympathetic nature.
The termination of vegetative fibres in dog tongue is also represented by
the terminalreticulum.

The filiform papillae are much smaller in scale than by man,
showing low cylindrical form containing 2 or 3 secondary papillae, with
very weak cornified surface of epithelium. The sensory fibres thereto
are correspondingly very few in number, and the terminations are in
general of simple unbranched or branched type consisting of medium
or small size fibres, but frequently of larger fibres showing change of size.
No intraepithelial fibres are found to exist. Corpuscular terminations as
seen in man also are lacking.

The fungiform papillae are small at the fore part of the tongue but
larger at the hinder part, with secondary papillae. In the epithelium
taste buds are often observed. The innervation is weak in the fore part,
but as we go backward, the nerves become better developed, with frequent
formation of basal plexus at the base. The sensory fibres originating in
it run into the papillae, to pass into simple branched and unbranched
or more complex plexuslike terminations. But also here, no corpuscular
terminations may be seen. But as the epithelium is covered by the corneous plate, formation of intraepithelial fibres may be observed, though in a weak development. The development of gustatory fibres to the taste buds is also poor, most of them being out of direct supply of intra- and extragemmal fibres.

In the canine foliate and circumvallate papillae, many taste buds exist not only in the epithelium facing the grooves but also in that facing the mouth cavity. But in the epithelium of the wall surrounding the circumvallate papillae, the existence of taste buds is very limited. At the base of these two kinds of papillae, conspicuous formation of basal plexus is seen, and the sensory fibres originating in it are better developed than in filiform and fungiform papillae, forming terminations of various forms under the epithelium. Simple unbranched terminations are little in number, branched terminations being prevalent. Branched terminations are further divided into simple and complex forms, the latter again into arborized and plexus-like terminations showing change in size and peculiar winding course of the fibres.

The development of sensory fibres to the taste buds in these papillae is rather good, but glomerular terminations observable in man cannot be found, only simple quasi-gglomerular bodies being formed rarely in the foliate papillae. However, similarly to the human counterparts, loop-like, plexus-like and other simple branched terminations are not lacking under the taste buds here. Intra- and extragemmal fibres often run into or around the taste buds, but these are generally unbranched, ending sharply, never in knob-like nor lamellar bodies. As many of these taste buds are observed without any direct supply of sensory fibres, it may be concluded that the development of the gustatory fibres is much inferior in dog tongue than by human being.

References

5) Nakayama, Tohoku Igaku Zassi, 1943, 33, 447 and 473; 1944, 34, 367 and 387.
6) Inazawa, ibid., 1949, 42, 37.
10) Hirano, Graefe's Arch., 1941, 142, 549.
11) Hatano, Tokyo Igakkai Zassi, 1925, 39, 433.