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MICROVASCULAR ARCHITECTURE OF THE FILIFORM PAPILLAE IN PRIMATES AND INSECTIVORES

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Abstract

The microvascular architecture of filiform papillae was investigated under a scanning electron microscope in man, Japanese monkeys, common squirrel monkeys, common marmosets, common tree shrews, large Japanese moles and dwarf shrews utilizing microvascular corrosion casts. Filiform papillae were circularly arranged in primates, and each of them was supplied by a hairpin capillary loop. These papillae sometimes were aggregated. The filiform papillae of Japanese monkeys exhibited markedly locational differences on the lingual dorsum and were supplied by circularly arranged capillary loops or by an intrapapillary capillary network. Small filiform papillae were located on an epithelial eminence in the lingual radix, each of them supplied by a low and simple hairpin capillary loop. The aggregated filiform papillae of common squirrel monkeys were less frequent without any locational differences. Low filiform papillae of common marmosets and tree shrews were simpler in form, being arranged in a circle and supplied by a simple hairpin capillary loop. The filiform papillae of insectivores were not arranged in a circle. The filiform papillae of dwarf shrews were supplied by an incomplete capillary ring without a loop. With respect to species differences, the circularly arranged capillary loops in man were most complicated and highly developed. Microvascular architecture of the filiform papillae of insectivores was much simpler, different from those observed in primates.

Key words: Microvasculature, filiform papilla, vascular corrosion casting, primates, insectivores, scanning electron microscope.

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Introduction

There are remarkable variations in the tongue and teeth morphology, and in the number, from and distribution pattern of the lingual papillae according to animal families and food habits (Kuramae, 1989; Nagato *et al.*, 1987). In particular, variations in the shape of filiform papillae and their distribution on the lingual dorsum are characteristic for animal species. The microvascular architecture of each papilla varies in proportion to its basic form. Previously, these structures have been examined in histological specimens injected with India ink (Kutuzov and Sicher, 1951, 1952) and recently in corrosion casts using scanning electron microscopy (Kishi *et al.*, 1975, 1990; Yamashita, 1985; Nagato *et al.*, 1987, Kuramae, 1989). So far, no comparative descriptions have been published.

The present paper deals with microvascular architecture of the filiform papillae in primates and insectivores, including common tree shrews classified between the primate and insectivore. The findings obtained, especially in man, the Japanese monkeys, common squirrel monkeys and common marmosets, which are different from each other on the living territory and food habits, are discussed with respect to those results obtained in other species from a comparative anatomical point of view.

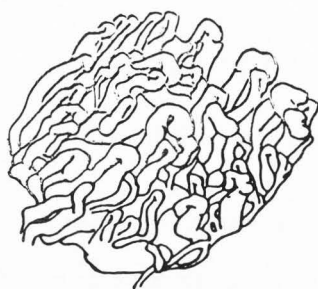
Materials and Methods

For this study, primates - man (*Homo sapiens*), Japanese monkeys (*Macaca fuscata fuscata*), common squirrel monkeys (*Saimiri sciureus*), common marmosets (*Callithrix jacchus*) and common tupais or tree shrews (*Tupaia glis*), and insectivores - large Japanese moles (*Mogera kobae*) and dwarf shrews (*Suncus murinus*) were utilized and assessed in terms of their comparative anatomy. Most of these primates were supplied by the Co-operative Research Fund of the Primate Research Institute, Kyoto University, since 1983. The human cadaver (70 years-old, male) donated for dissection in our university, was perfused 24 hours postmortem. The common carotid arteries were cannulated and the vascular bed was rinsed with heparinized isotonic saline solution,

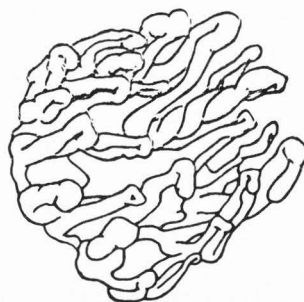
Table 1: Microvascular architecture of the lingual papillae in primates and insectivores.

PRIMATE

Human

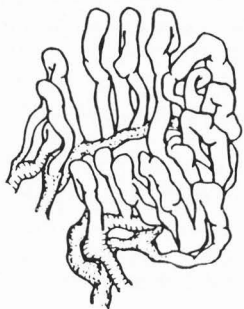


(Lingual Apex)



(Lingual Body and Radix)

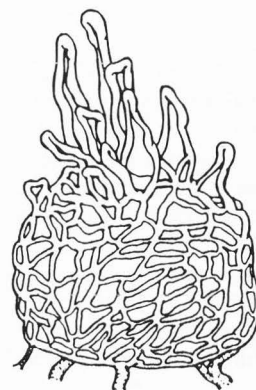
Japanese Monkey



(Lingual Apex)

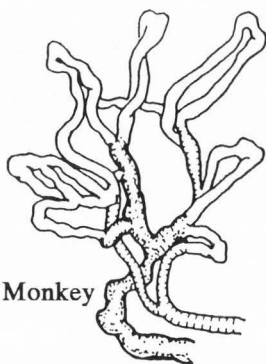


(Lingual Body)

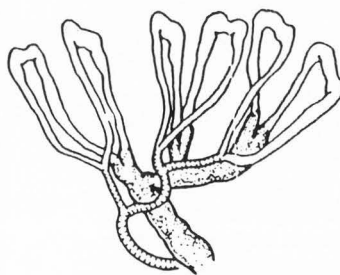


(Lingual Radix)

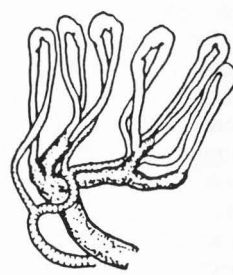
Squirrel Monkey



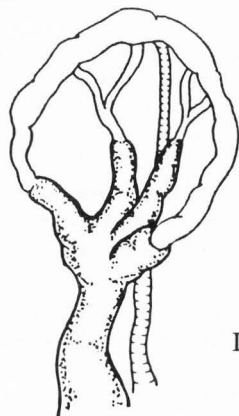
Marmoset



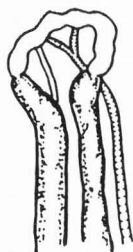
Tree Shrew



INSECTIVORE

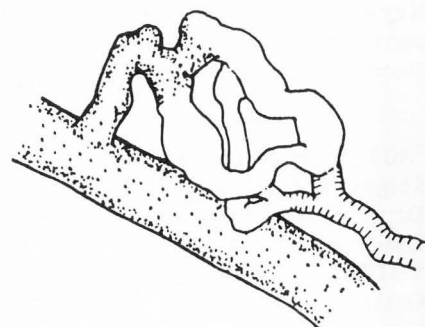


(Lingual Apex)



(Lingual Body and Radix)

Large Japanese Mole



Dwarf Shrew

5000 IU/l, at 37 °C. The animals were anesthetized by intraperitoneal administration of pentobarbital (40 mg/kg body weight) and perfused through the cannulated ascending aorta with heparinized isotonic saline solution, 5000 IU/l.

For scanning electron microscopy (SEM), blood vessels of the tongue were injected with methyl methacrylate plastics (viscosity: 23 centipoises, 70% glycerin at 20 °C) according to the plastic injection method of Ohta *et al.* (1990) via common carotid arteries in all species. After the bodies were left for 2 hours at room temperature for polymerization of the injected plastic, the tongues were carefully dissected out with a razor blade. This material was macerated in 5% NaOH solution at 60 °C for 12 hours, washed thoroughly in running water and air-dried. All SEM specimens were sputter-coated with gold in a vacuum evaporator (JFC 1500, JEOL) and observed under a JEOL JSM T-300, SEM, operating at an accelerating voltage of 5 kV and a working distance of 40 mm.

Results

Basic vascular architecture of the tongue

The deep lingual artery sent off numerous arterioles upwards which formed an arteriolar network in the lamina propria of the lingual dorsum after penetrating the lingual aponeurosis. From this network, arterioles arose toward the lingual papillae, and capillaries diverged to form the subepithelial capillary network. This arteriolar network was observed in its complete aspect in man and the Japanese monkeys, coarse in squirrel monkeys and marmosets, but was not observed in tree shrews or insectivores.

Microvascular architecture of the lingual papillae in primates (Table 1)

Filiform papillae in primates were either aggregated and/or circularly arranged. A hairpin capillary loop was observed in each papilla.

Man Lingual apex: Aggregated filiform papillae (Fig. 1) were observed in a double circular arrangement, approximately 20 filiform papillae arranged in an outer circle and about 10 in an inner circle. Each papilla was supplied by a capillary loop via 3 or 4 arterioles which arose from the arteriolar network directly beneath the aggregated filiform papillae. The capillary entering the papilla was usually inconstant and larger (20 μ m) in diameter than those in the capillary network of the inter-papillary areas. Swellings were observed near the tip of the capillary loop supplying the internal papillae.

Man Lingual body and radix (Fig. 2): About 20 filiform papillae were externally arranged in a circle, the diameter of which was enlarged on account of the expanded intervals between the papillae. The internal papillae decreased in number (3 or 4). The vascular architecture was similar to that in the filiform papillae on the lingual apex, with swollen and twisted capillary tip.

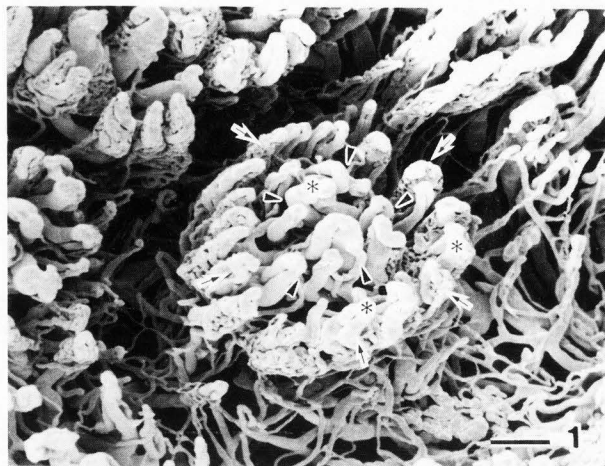


Figure 1. Filiform papillae of the lingual apex in man, arranged in two circles. Each circle is supplied by a capillary loop with a swelling (*) at its tip. Outer circle is marked with arrows, inner circle with arrowheads. Bar = 100 μ m.

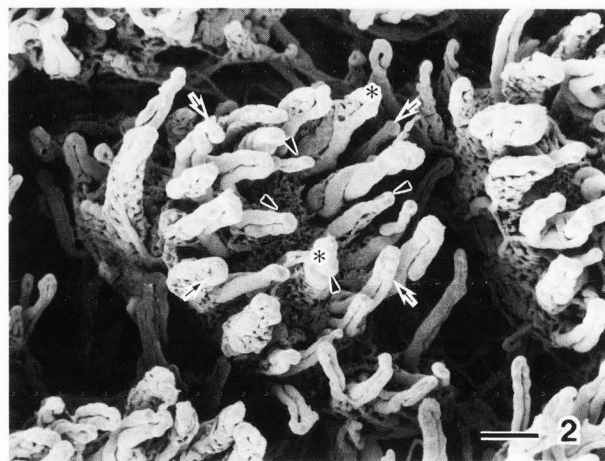
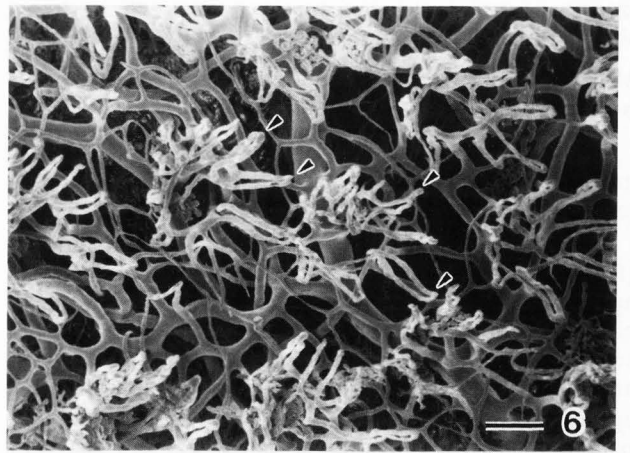
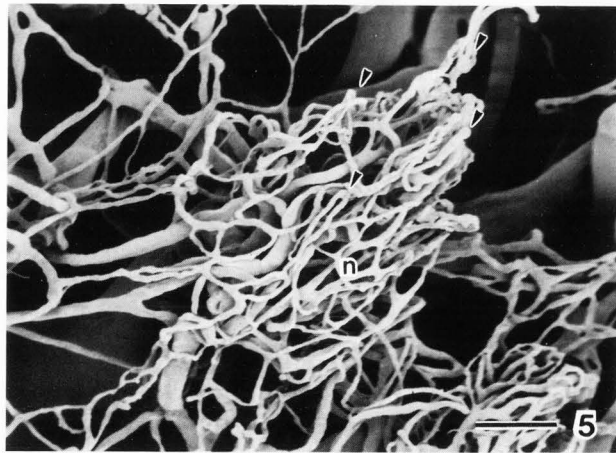
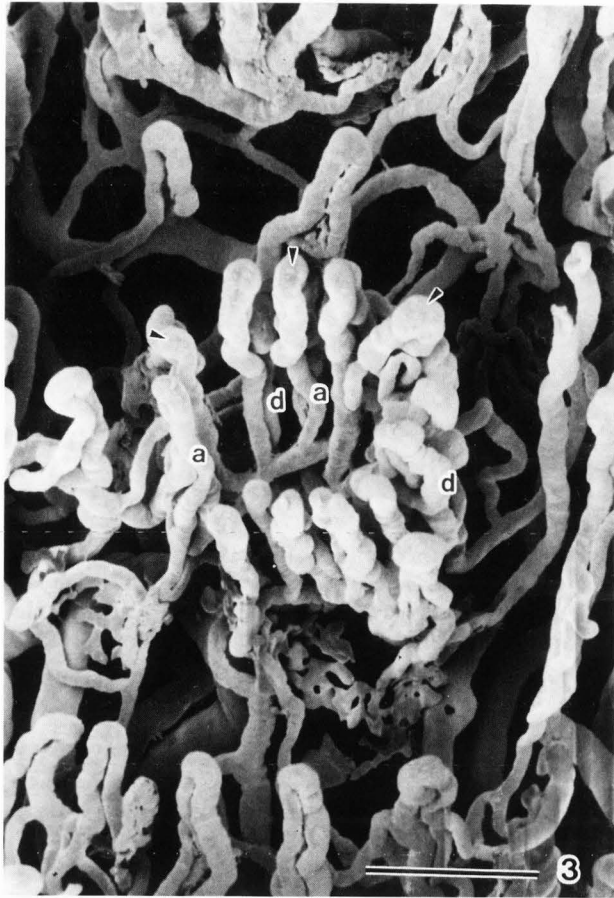


Figure 2. Filiform papillae of the lingual body and radix in man, resembling those of the lingual apex. Inner circular filiform papillae (arrowheads) decrease in number. Arrows mark the outer circle, swelling (*) at the tip of the capillary loops. Bar = 100 μ m.

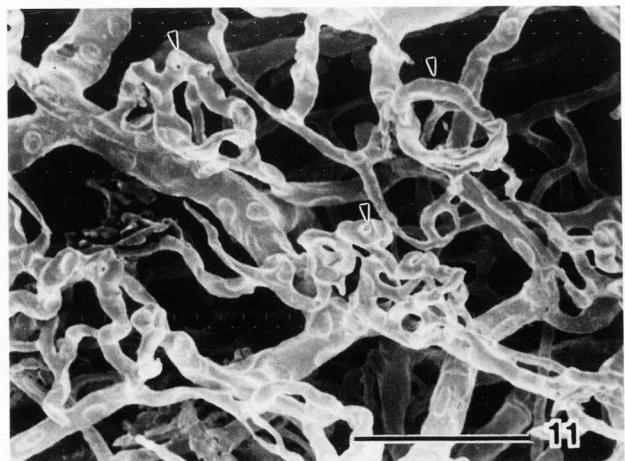
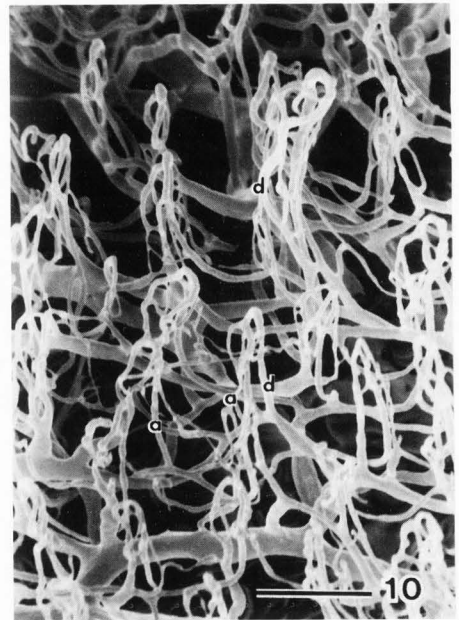
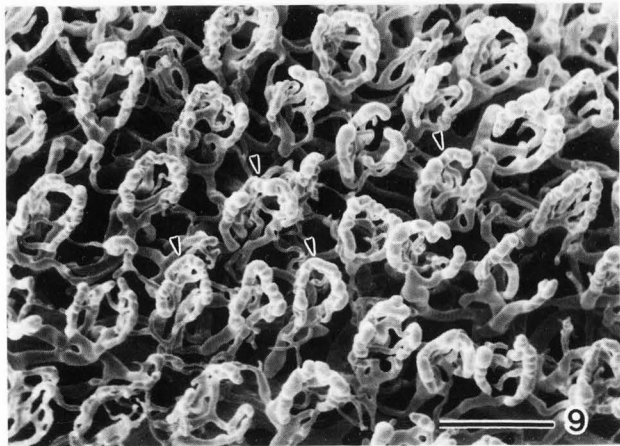
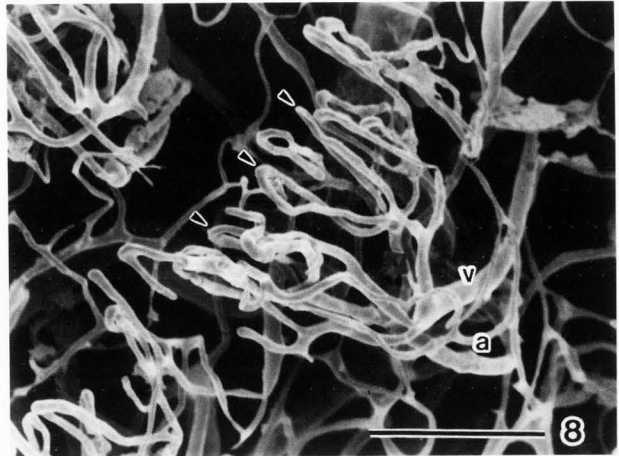
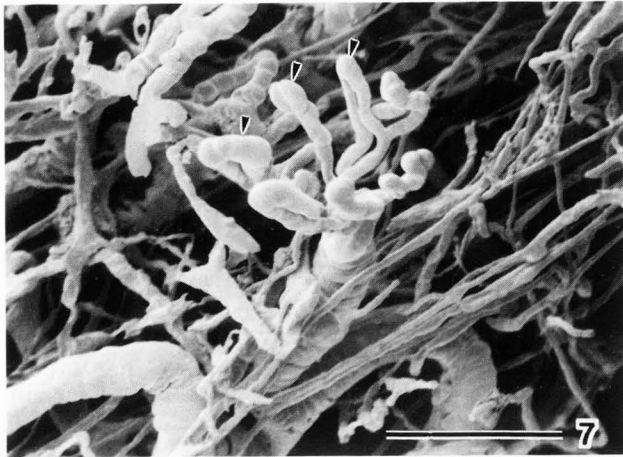
Japanese monkey Lingual apex (Fig. 3): Two or three arterioles arising from the arteriolar network in the lamina propria passed directly beneath the circularly arranged filiform papillae and gave rise to a simple capillary loop supplying each papilla after ramifying. The capillary loop irregularly swelled at its tip. A simple, low filiform papilla located in the center of the circularly arranged filiform papillae was supplied by a low capillary loop.



Figures 3 - 5. Filiform papillae of the lingual apex (**Fig. 3**), lingual body (**Fig. 4**), and lingual radix (**Fig. 5**) in the Japanese monkey. In **Fig. 3** capillary loops supplying the circularly arranged filiform papilla also appear in a circular pattern. Arrowheads indicate swellings at the tip of the capillary loops. In **Fig. 4** a conical filiform papilla is supplied by the intrapapillary capillary network and tall loops (arrowheads) at its top. Ascending crus (a), descending crura (d). In **Fig. 5** Each papilla is supplied by a simple, low capillary loop (arrowheads) arising from the subepithelial capillary network (n). Bars = 100 μm .

Figure 6. Filiform papillae in the common squirrel monkey. Each papilla is supplied by a simple hairpin capillary loop (arrowheads), all of which appear together in form of a crown. Bar = 100 μm .

Microvasculature of the filiform papillae



Figures 7-11. Filiform papillae in:

Figure 7. The common marmoset. A simple, low hairpin capillary loop (arrowheads) supplies each papilla. All loops together appear in shape of opened petals.

Figure 8. The common tree shrew. Each of the circularly arranged papillae is supplied by a simple hairpin capillary loop (arrowheads), arteriole (a), venule (v).

Figure 9. The lingual apex in the large Japanese mole. Capillary loop supplying the papilla appears as a ring (arrowheads) by anastomoses at their tips.

Figure 10. The lingual body and radix in the large Japanese mole. The hairpin capillary loop is drained via a thick descending crus (d), ascending crura (a).

Figure 11. The dwarf shrew. The capillary forms a low and incomplete ring (arrowheads) in a papilla. Its capillary is irregular in diameter and drains into a thicker descending crus (d).

Bars = 100 μ m.

Japanese monkey Lingual body (Fig. 4): The filiform papillae were not arranged in circles, and were rather distributed as single conical-shaped structures on the lingual body. Arterioles arising from the arteriolar network in the lamina propria ascended into the center of the papilla and formed an intrapapillary network in form of a cone. High capillary loops were observed in the apex of the papilla.

Japanese monkey Lingual radix (Fig. 5): Aggregated filiform papillae, consisting of six or seven low papillae, were located on the epithelial eminence. The papilla was supplied by a simple, low capillary loop arising from the subepithelial capillary network.

Common squirrel monkey (Fig. 6): Filiform papillae, 7 or 8 in number, were arranged in a circle without locational differences. An arteriole arising from the arteriolar network in the lamina propria passed directly beneath the filiform papilla, where it spread to capillaries supplying each filiform papilla in shape of opened petals or crowns.

Common marmoset (Fig. 7): Each of the circularly arranged papillae, 5 or 6 in number, was supplied by one arteriole which gave rise to a simple, low hairpin capillary loop into each papilla. Entire capillaries had the shape of opened petals. The descending crus of the loop drained into a venule.

Common tupais (tree shrew) (Fig. 8): The arrangement of the filiform papillae and the shape of the capillary loop were similar to those in common marmosets.

Microvascular architecture of the lingual papillae in insectivores (Table 1)

No circular arrangement of the filiform papillae was observed. They were located in a line anterolateral to the median line of the lingual dorsum. The arteriolar network was not formed in the lamina propria.

Large Japanese mole Lingual apex (Fig. 9): Two or three capillaries arising from an arteriole continued into the papillae to form loops. Their tips anastomosed with one another in a ring shape. Capillaries in the anastomoses were irregularly swollen. The descending crura (20 μm) were about twice as thick as the ascending crura (10 μm) in diameter.

Large Japanese mole Lingual body and radix (Fig. 10): A capillary arising from the arteriole formed a hairpin loop which continued to the descending crus (20 μm), similar to the thickness of that in the lingual apex.

Dwarf shrew: Capillary loops as observed in other species were missing, but a capillary arising from the arteriole formed an incomplete ring in each papilla after ramifying. The capillary was not regular in diameter and drained into a thicker descending crus. This capillary ring was located superficial to and in contact with the arteriolar network in the lamina propria.

Discussion

Differences as to the location and form of filiform papillae on the lingual dorsum have been described in various species of mammals, but the comparative anatomical and evolutionary details have not been discussed. The present study attempts to make detailed investigation and to discuss the comparative morphology and microvasculature of the filiform papillae in certain primates and insectivores, as summarized in Table 1.

Kutuzov and Sicher (1951, 1952) made an interesting suggestion that the respective region of the palate in the rat may correlate closely with the respective filiform papilla distribution on the lingual dorsum in functional fields, deducing from their macroscopic and light microscopic findings.

Kuramae (1989) and Nagato *et al.* (1987) investigated the form of the filiform papillae and their microvasculature in the rat and divided them into six types, suggesting that differences in location and form may have a close relation to food habits and may therefore designate the respective role assigned by locational function.

Among the primates observed, the transverse palatine plicae were not developed in man and were absent in the intermolar region. Kishi *et al.* (1975) reported that one capillary in the filiform papilla of man branched in shape of a fan, which formed hairpin loops to supply filiform papillae. No locational differences among filiform papillae were observed, although the microvascular architecture of the papilla was most complicated in man. In addition to masticatory movements, the tongue of man is used in extremely complicated movements concerning the development of the speech function. In order to perform these tongue movements, the formation of a densely complicated microvascular architecture in the lingual dorsum is always necessary to maintain blood supply. Accordingly, such a formation is much more developed in the lingual apex than in the radix in correlation with movement aspects of the apex. Yu *et al.* (1992) designated the capillary loops in the filiform papilla of 0.5 to 2 year-old human infants as a corolla pattern. This structure is uniform with the circularly arranged capillary loops mentioned in this paper. Papillae are neither arranged in circles nor they show different shapes in infants; they rather reveal a simple form. Three types of capillary loops in filiform papillae, as suggested by Kishi *et al.* (1990) and Yu *et al.* (1992), could not be identified in the present study. Swellings in the tip of capillary loops make their extent wider, since they are always affected by external forces.

In Japanese monkeys, topographic differences among filiform papillae are marked (Mitsui, 1990), and the transverse palatine plicae are also fairly well developed among the primates studied (Japanese monkey: Kajiwara, 1989; common squirrel monkey: Inoue and Toda, 1991). This designates apparently a functional assignment of location on the lingual dorsum according to food habits. Generally, the food habits of the

macaque family, originally a tree dwelling monkey, have changed rapidly to a variety of foods as they have become ground dwellers. This change also demands the development of various regions of the oral cavity. Kutuzov and Sicher (1952) suggested that the anteromolar region of the oral cavity in the rat plays the role of a discriminatory region, the intermolar area, a supplementary masticatory function and the postrugal field, that of a gustatory organ, namely, the final discriminatory region. Based on their suggestions, the locational differences in papilla form in the Japanese monkey may be as follows. The circularly arranged and aggregated filiform papillae in the lingual apex and radix may be suitable for performing food discriminatory functions. Single large conical papillae may assist masticatory function and transport food masses into the pharynx, preventing reflex of such masses, in cooperation with transverse palatine plicae.

The microvascular architecture of common squirrel monkeys appears similar to that of common marmosets. Since both species are tree dwellers, their food habits are restricted, making masticatory movements relatively simpler than in the Japanese monkey and man. The squirrel monkeys usually have a wider food gathering territory than that of marmosets. In this manner, squirrel monkeys may eat more kinds of foods. This ecology of the squirrel monkeys is reflected in more complicated pattern of the microvascular architecture of the filiform papillae.

The microvasculature of the filiform papillae in tree shrews differs from that in insectivores but is very similar to that in the common marmosets since tree shrews are tree dwellers. Based on the microangiological findings, tree shrews may be situated close to the primate family.

In large Japanese moles (an insectivore), two kinds of filiform papillae are observed on the lingual apex and radix, with apparent differences between the two in terms of type of microvasculature (Yamashita, 1985). Such a functional development may be caused by the ingestion of large amounts of food by this species, in contrast to the body weight of the mole. The filiform papillae in musk shrews (*Soricidae*) were described as conical-shaped filiform papillae and the upper part of each papilla was branched into several pointed processes by Iwasaki *et al.* (1987). The tongue of the dwarf shrew is scarcely involved in masticatory movement, however, so that no locational difference appears and the capillary loop in the filiform papilla is not sufficiently extended.

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Discussion with Reviewers

S. Yoshida: Takaki T (Studies of the cell proliferation of carcinogenesis process on tongue carcinoma of rats induced by 4-nitroquinoline 1-oxide. part 1.: Relation between morphology and microvascular architecture of filiform papilla of tongue dorsal surface of the normal albino rats. *Shikwa Gakuho* **86**: 357-378, 1986, in Japanese) suggested that a high degree of correlation existed between the vascular supply and epithelial cell proliferation of the lingual papilla. Please comment on the relevance of that work to your paper.

Authors: We agree with Takaki's suggestions only regarding the cell proliferation and vascular supply, but our results on the normal aspect cannot demonstrate relations between them.

S. Aharinejad: You explain the arterial supply of the papillae, whereas the venous drainage seems to lag behind. Are the veins provided with valves? Do any other peculiarities of veins, e.g., sphincters, exist?

Authors: Venous valves and sphincters were not observed but arterio-venous anastomoses on the lingual dorsum were reported in the Japanese monkey by Nakamura and Okada (*Microvascular architecture of the lingual papillae in the Japanese monkey. Okajimas Folia Anatomica Japonica* **69**: 183-198, 1992). We do not know of studies focusing on these structures in primates and insectivores.

T. Tokioka: A hairpin capillary loop was observed in each papilla. Are there secondary papillae in one papilla? Are there any capillaries in the secondary papillae?

Authors: Secondary papillae were not observed in filiform papillae of the lingual apex and radix.

M.K.M. Pang: Can the authors explain the function of swellings at the tip of capillary loops in the filiform papillae?

Authors: We speculate that the swelling may act as a buffer zone counteracting external forces.