Studies on the Papilla Foliata of Japanese.

I. The number of papillae foliatae.

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with 11 text-figures.

Introduction.

The author reported already elsewhere of his study on papillae vallatae and also the number of taste buds. In this paper the author records the results of an investigation on papilla foliata by using the material previously collected as well as some that has lately come to hand.

Weber and A. F. J. C. Mayer (1842) first gave the name papilla foliata to these organs on the tongue. W. Krause (1870) discovered the taste buds on papilla foliata. Ajtai (1872) investigated further and said that papilla foliata has a small number of the taste buds and the papillae are arranged irregularly. Furthermore, he states that when the papillae foliatae of human being are compared with those of rabbits, the former appear as a mere trace.

F. Tuckerman (1888) describes that the human papillae foliatae look like a trace and apparently are formed by several irregular furrows of mucous membrane. The structural appearance is by no means similar. They vary from the primitive type to well developed forms. He examined the tongues of human fetus of four month and a half to five month old and found that the furrows between the papillae foliatae are not developed; whereas those of a seven month old fetus have seven or eight furrows.

Victor von Ebner (1873) no doubt did the most thorough investigation on the papilla foliata of man. He describes that the papillae foliatae are a part of the furrows of the lateral line of the tongue and the taste buds are found in them, and there are tongue ducts near them. The shape varied

and they are not uniform. The furrows either cross the lateral line of the tongue or run irregularly along the lateral line. In those furrows there are smaller furrows. These latter furrows are usually pressed against on one side, and they are not easy to distinguish from general mucous membrane. The taste buds are only found in two or three furrows and not in all of them. The rest of the furrows do not have the taste buds. Köllikers Handbuch also mentions the irregularity of the distribution of the taste buds in papillae foliatae.

H. Stahr (1903) examined a considerable number of human tongues of adults, infants and fetus and said that the papillae foliatae are in perfect shape during the lactation period, but in adults some are normal whereas the others are degenerated to a mere trace. The degenerated papillae have a lesser number of taste buds than normal. The degeneration of papilla is characterized by the changes of the shape of papilla, decrease of the number of taste buds as well as the atrophy of serous glands, and increase of fat cells and appearance of lymph nodules.

The other investigators on papilla foliata are Lovén (1868), von Wyss (1869), Hönnigschmied (1873), Hermann (1885), Gmelin (1892), Lenhosséck (1893), Gråberg (1898, 1899), Stahr (1903, 1906), Kolmer (1910), Heidenhain (1914), Huber u. Eggerth (1917), Okada (1928), Mikami (1931) and Miyazaki (1933). All these investigators gave elaborate descriptions on the development of papilla and minute structures of the taste buds, but none had undertaken to determine the number of the papillae foliatae according to the age or that of the taste buds. It therefore became the task of the present author to investigate the above problem on the tongues of Japanese.

Materials and Methods.

The larynx was excised from the corpse, and the tongue fixed in 10% formalin or in Zenker's solution. The papillae foliatae were taken out with surrounding tissues from both lateral ridges of the tongues.

The range of ages from which the materials were collected was from a new born infant to a ninety year old adult. The total number of tongues was 115, and 230 clusters of papillae foliatae were examined.

After the materials were thoroughly washed in water, the usual method of dehydration in alcohol was carried out. In order to prevent the contraction of the tissues, the materials were immersed in cedar wood oil, and were embedded in paraffin.

The sections were mostly cut parallel to the free surface 20μ in thick-

ness. They were stained in haematoxylin-eosin double staining. Some papillae were cut at right angles to the free surface. The two types of sections were carefully compared in order to insure accuracy of observation.

Fig. 1. The photograph of the free surface of the papillae foliatae.

The papillae foliatae in man are found on the lateral ridge at the root of the tongue and the papillae run parallel dorso-ventrally of the tongue, and there is a small forrow between each papilla. Their development is irregular. There is no marked definition to differentiate a papilla from surrounding tissues as it is clearly shown in the rodent family, especially in the case of the rabbit. However, even those indistinct papillae, so far as optical observation can ascertain, might contain the taste buds if the sections were

Fig. 2. Micro-photograph. The sections are cut at right angles to the free surface to show the arrangement of the papillae foliatae. $\times 10$.

examined under the microscope.

On the other hand, material which appears to be true papilla to the naked eye may reveal no taste bud at all. Consequently there will be numerical differences of the numbers of papillae which are determined by optical observation and microscopical examination. The author counted the papillae in the series of sections in order from the beginning to the end, and took into account only those which had the taste buds as true papilla and those without were discarded.

The surface and lateral layers of papilla are composed of squamous epithelium and lamina propria under epithelium. The structure of epithelium along the lateral edge of the tongue is practically the same throughout. They are also the same in the free surface of papillae and in the walls of furrows. The extreme outer surface is covered with the cornified layer. The thickness of the epithelium differs according to the regions where it is found. It is somewhat thicker in the free surface of papilla than at the side of walls of furrows. But even those which are in the side walls the epithelium are much thicker in the region where there are much taste buds than that which is found in the place where there is no taste buds.

The size of papilla also differs. The papillae in the middle section of the cluster or those in back are comparatively

Fig. 3. Micro-photograph. Cross section showing one of the types of the shape of papilla foliata. $\times 20$.

Fig. 4. Micro-photograph. Cross section showing another type of the shape of papilla foliata. $\times 20$.

larger than those in front. Consequently the furrows between the papillae are narrow and shallow. (Fig. 1 and 3).

The cross sections of papilla foliata, however, show various types of shapes. Some are triangular with smooth corners, fig. 3; whereas the other are ellipsoidal, fig. 4; but in the majority of cases they are spindle shaped and they are arranged parallel to their own longitudinal axis, fig. 5.

The examinations of the series of these sections revealed the facts that the surface area of a given individual papilla may have a wider surface near the free surface and becomes narrow at the basal end while in the other material the condition is reversed, fig. 2. There are apparently two types of papillae; one having a heavy top and the other having a thick base.

There are cases in which one papilla apparently united with another in one case and in another a single papilla had branched out into two papillae, fig. 6. In order to determine one way or the other as to whether a given papilla is a

union of two or one has bifurcated into two lobes, the serial sections were examined carefully with reference to the taste buds. If the taste buds are found in between the free surface of the papilla and the point of the union where two lobes are united the case was decided as a fusion of two papillae. If the taste buds are present only at the basal part, below the joint of two lobes, it was regarded as bifurcation of one papilla into two papillae.

Fig. 5. Micro-photograph. Cross section showing the third type of papilla foliata. $\times 10$.

Fig. 6. Micro-photograph. Cross section of papillae, the third from the right shows the union of two papillae. $\times 10$.

Observation.

The number of papillae foliatae in the tongue.

The numerical determination of the papillae foliatae was based on the conditions stated above. The results of the observation are tabulated in tables 1 and 2. The maximum number of papillae thus found in the tongues was 17 and the minimum was 5. The majority had 10 or 11 and the cases comprised almost 16.5% of the total findings. It is very significant that the gradation of the number of papillae foliatae gradually decreases from these standard numbers toward both to maximum and minimum. The average number of papillae foliatae in our investigation was 10.9 per tongue.

Table 1. The numerical determination of papillae foliatae in tongues.

number of tongues	total number of papillae foliatae	maximum number per tongue	minimum number per tongue	average	standard deviation	probable error
115	1 253	17	5	10.9	± 2.76	± 0.25

Table 2. The distribution frequency in which the number of papillae foliatae were found in the tongues.

number of papillae	number of cases and percentages	number of tongues	
		I	I 5
		number of cases	percentage
5		3	2.6 ± 1.48
6		7	6.1 ± 2.23
7		4	3.5 ± 1.71
8		6	5.2 ± 2.06
9		13	11.3 ± 2.95
10		18	15.7 ± 3.39
11		19	16.5 ± 3.46
12		13	11.3 ± 2.95
13		11	9.6 ± 2.74
14		8	6.9 ± 2.36
15		6	5.2 ± 2.06
16		6	5.2 ± 2.06
17		1	0.9 ± 0.87

The number of the papillae foliatae at the lateral ridge of tongues.

The number of papillae in the papilla foliata cluster at the baso-lateral end of the tongues was counted. Tables 3 and 4 give the results. In 230

clusters from both sides of 115 tongues there was a maximum of 9 and minimum of 2 papillae in a cluster. Five papillae in a cluster, however, was most common and such cases comprised almost 28.3% of all. The cases of 6 papillae in a cluster came next, 24.4%. The other numbers gradually decreased toward both ends, maximum and minimum. The average number of papillae in a cluster is 5.4.

Table 3. The number of papillae foliatae in the papilla foliata cluster.

number of tongues	number of clusters in both sides	number of papillae	maximum number per tongue	minimum number per tongue	average	standard deviation	probable error
115	230	1 253	9	2	5.4	± 1.45	± 0.09

Table 4. The distribution frequency in which the number of papillae foliatae were found in the tongues.

total number of papilla clusters number of cases and percentages number of papilla	2 3 0	
	number of cases	percentage
2	3	1.3 ± 0.74
3	21	9.1 ± 1.89
4	32	13.9 ± 2.28
5	65	28.3 ± 2.96
6	56	24.4 ± 2.84
7	32	13.9 ± 2.28
8	18	7.8 ± 1.78
9	3	1.3 ± 0.74

The numerical comparison of the papillae on the right and left hand side of the tongues.

Tables 5 and 6 show the numerical comparison of the number of papillae in the papilla foliata cluster on the right and left hand side of the tongues.

Table 5. The number of papillae foliatae in the right and left lateral side of the tongues.

number of tongues	lateral ridge	number of papillae	maximum number	minimum number	average	standard deviation	probable error
115	right	627	9	2	5.5	± 1.50	± 0.14
	left	626	9	2	5.4	± 1.45	± 0.13

Figure 7 is a graphical reproduction of table 6. Tables 5 and 6 and figure 7 show that the minimum of the papillae on the right and left hand side was 2

Table 6. The distribution frequency of the papillae foliatae in the right and left lateral side of the tongues.

number of the tongues and percentages	right		left	
number of papillae	number of cases	percentage	number of cases	percentage
2	1	0.9 ± 0.87	2	1.7 ± 1.20
3	11	9.6 ± 2.74	10	8.7 ± 2.62
4	16	13.9 ± 3.22	16	13.9 ± 3.22
5	31	26.9 ± 4.13	34	29.6 ± 4.25
6	30	26.0 ± 4.09	26	22.6 ± 3.90
7	16	13.9 ± 3.22	16	13.9 ± 3.22
8	9	7.9 ± 2.51	9	7.9 ± 2.51
9	1	0.9 ± 0.87	2	1.7 ± 1.20

and the maximum was 9. The cases of 5 or 6 papillae on the left lateral side was more predominant than the other numbers in the right lateral side, each being 26.0% of total. The combination of these two cases makes over 50% of all. While on the left lateral side, 5 papillae was most numerous (29.6%) and 6 papillae came next (22.6%). The average number of papillae in the right lateral side was 5 and that in the left lateral side was 5.4. There was very little difference between them (0.1 ± 0.19).

Fig. 7. The graphic reproduction of tables 5 and 6.

**Relativity of the number of papillae in the right
and left hand side of the tongues.**

In some cases the number of papillae in the papilla foliata cluster is correlated, and in other cases it is not. Table 7 shows the cases in which the number of papillae in the right and left lateral side is exactly correlated.

Table 7. Cases in which the number of papillae in the right
and left lateral side of the tongues is same.

number of papillae		number of cases	percentage
right	left		
3	3	7	6.0 ± 2.21
4	4	6	5.2 ± 2.06
5	5	15	13.0 ± 3.13
6	6	11	9.6 ± 2.74
7	7	6	5.2 ± 2.06
8	8	4	3.5 ± 1.71
total		49	42.5 ± 4.61

Table 8. Non-relative cases of the number of papillae found
in the right and left lateral side of the tongues.

right < left			right > left		
number of papillae	number of cases	percentage	number of papillae	number of cases	percentage
right : left			right : left		
2 : 3	1	0.9 ± 0.87	3 : 2	2	1.8 ± 1.23
3 : 4	2	1.8 ± 1.23	4 : 3	2	1.8 ± 1.23
4 : 5	7	6.0 ± 2.21	5 : 4	6	5.1 ± 2.73
4 : 6	1	0.9 ± 0.87	6 : 4	2	1.8 ± 1.23
5 : 6	8	6.9 ± 2.36	6 : 5	11	9.5 ± 2.73
5 : 7	1	0.9 ± 0.87	7 : 5	1	0.9 ± 0.87
6 : 7	5	4.3 ± 1.88	7 : 6	5	4.3 ± 1.88
5 : 8	1	0.9 ± 0.87	8 : 6	1	0.9 ± 0.87
6 : 8	1	0.9 ± 0.87	8 : 7	3	2.6 ± 1.48
7 : 8	3	2.6 ± 1.48	9 : 7	1	0.9 ± 0.87
7 : 9	1	0.9 ± 0.87		34	29.6 ± 4.28
8 : 9	1	0.9 ± 0.87			
	32	27.9 ± 4.18			

total of 66 cases ($57.5 \pm 4.51\%$)

Such cases represent 42.5% of the total findings. The cases of such correlations are found in the clusters which have the number of papillae from 3-8 per cluster. The correlative number of 5 papillae in a cluster being the highest (13.0%) and that of 6 papillae (9.6%) came next.

The cases in which the number of papillae in the right and left lateral side was not correlated are given in table 8. The number of papillae in the right lateral side was bigger than that of the left side was found to be about 29.6% of total results. Cases of 6 papillae in the right and 5 in the left were most numerous (9.5%), 5 in the right and 4 in the left was second (5.1%), and 7 in the right and 6 in the left was third (4.3%).

The number of papillae on the left lateral side was greater than that of the right side, 27.9%. The cases of 5 papillae in the right hand side and 6 in the left was 6.9% : 4 in the right and 5 in the left (6.0%); 6 in the right and 7 in the left was 4.3%.

In general there were slightly more cases of noncorelative correlation in the number of papillae on the right and left lateral side than otherwise. The differences of these two being $15.0 \pm 6.44\%$. But the actual numerical differences of the papillae which was found in the right and left lateral side of the tongues are very slight. The differences were only $1.7 \pm 5.98\%$.

The number of papillae foliatae and sex.

The comparative studies with reference to the number of papillae foliatae between male and female are produced in tables 9 and 10. Examination of the tables 9, 10 and figure 8 give the following conclusions that in male the maximum number of the papillae was 17 and the minimum 5. The maximum frequency of the number of papillae in male, however, 11. It is 17.5% of 63 materials. Twelve papillae came next (14.1%); 9 and 10 papillae each the third (12.7%). The average was 11.2 papillae per tongue.

In the case of the female, 16 papillae was the maximum number and 5 was the minimum. The maximum frequency was 10 papillae (19.3%) and 11 was next (15.4%). The average was 10.6 papillae per tongue. The difference of the number of papillae between the male and female was very little, 0.6 ± 0.50 .

Table 9. The number of papillae foliatae in male and female.

sexes	number of tongues	number of papillae	maximum per tongue	minimum per tongue	average	standard deviation	probable error
male	63	705	17	5	11.2	± 2.76	± 0.34
female	52	548	16	5	10.6	± 2.70	± 0.37

Table 10. The distribution frequency of the number of papillae foliatae in male and female.

number of papillae	sexes		male		female	
	number of cases and percent- ages	number of tongues	63		52	
			number of cases	percentage	number of cases	percentage
5	1		1	1.6 ± 1.57	2	3.8 ± 2.65
6	3		3	4.8 ± 2.69	4	7.7 ± 3.72
7	2		2	3.2 ± 2.21	2	3.8 ± 2.65
8	3		3	4.8 ± 2.69	3	5.8 ± 3.24
9	8		8	12.7 ± 2.02	5	9.6 ± 4.08
10	8		8	12.7 ± 2.02	10	19.3 ± 5.47
11	11		11	17.5 ± 4.78	8	15.4 ± 5.00
12	9		9	14.1 ± 4.38	4	7.7 ± 3.54
13	5		5	7.9 ± 3.39	6	11.5 ± 4.42
14	4		4	6.4 ± 3.04	4	7.7 ± 3.64
15	3		3	4.8 ± 2.69	3	5.8 ± 3.24
16	5		5	7.9 ± 3.39	1	1.9 ± 1.89
17	1		1	1.6 ± 1.57	—	—

Fig. 8. The graphical reproduction of the number of papillae in male and female.

The numerical comparison of papillae foliatae and age groups.

The total number of the tongues which were examined in this investigation was 115. They were divided in 3 age groups; juvenile period (Birth-20 years old) maturity period (21-60 years old) and old age period (61-90 years old). The difference in number of papillae foliatae with reference to the ages are given in tables 11 and 12 also in figure 9.

In the juvenile period, the number of papillae runs between the minimum

Table 11. The number of papillae foliatae in the tongue according to different ages.

age	number of tongues	number of papillae	maximum per tongue	minimum per tongue	average	standard deviation	probable error
juvenile	37	448	17	5	12.1	± 2.80	± 0.46
maturity	40	412	16	5	10.3	± 2.45	± 0.38
old age	38	393	16	5	10.3	± 2.69	± 0.43

Table 12. The distribution frequency of papillae foliatae and age.

number of papillae	number of cases and percentages	age		juvenile		maturity		old age					
		number of cases	percentage	number of cases	percentage	number of cases	percentage						
								37		40		38	
5	1	2.7±2.65	1	2.5±2.46	1	2.6±2.58							
6	2	5.4±3.71	2	5.0±3.44	3	7.9±4.37							
7	—	—	2	5.0±3.44	2	5.3±3.67							
8	1	2.7±2.65	3	7.5±4.16	2	5.3±3.67							
9	1	2.7±2.65	6	15.0±5.64	6	15.8±5.67							
10	3	8.1±4.48	7	17.5±6.00	8	21.0±6.60							
11	5	13.5±5.61	10	25.0±6.84	4	10.5±4.98							
12	6	16.2±6.05	3	7.5±4.16	4	10.5±4.98							
13	7	19.0±6.44	1	2.5±2.46	3	7.9±4.37							
14	4	10.8±4.83	2	5.0±3.44	2	5.3±3.67							
15	3	8.1±4.48	2	5.0±3.44	1	2.6±2.58							
16	3	8.1±4.48	1	2.5±2.46	2	5.3±2.58							
17	1	2.7±2.65	—	—	—	—

Fig. 9. The percentage of the distribution frequency of papillae foliatae was plotted according to the age groups.

of 5 to the maximum of 17. Thirteen papillae was most numerous in this group, and it represents almost 19.0% of the total. Twelve papillae came next, about 16.2%. The average shows 12.1 per tongue in the group. In the maturity period the minimum was 5 and the maximum was 16, and the cases of 11 papillae were more numerous, 25.0%. Ten papillae came next (17.5%). The average was 10.3 papillae per tongue. The average number of papillae in this group is slightly smaller than that of the juvenile period.

Fig. 10. The sections are cut parallel to the free surface of papillae foliatae. $\times 15$. The material is from a new born infant.

The difference of these two period is 1.8 ± 0.59 per tongue. The finding in the old age period was practically the same as that of the maturity period. Five papillae was the minimum and 16 was the maximum. The most numerous case were 10 papillae (21.0%) and 9 came next (15.8%). The average was 10.3 per tongue, and the number was still slightly smaller than that of the juvenile period. The difference between this period and the juvenile period was 1.8 ± 0.62 , and with that of the maturity period was 0 ± 0.57 per tongue.

Most of the papillae foliatae in the juvenile period are found arranged irregularly, fig. 10. The grooves between papillae are narrow and shallow. In the maturity period the grooves are deep, and the papillae gradually attain a definite form and become spindle shaped. The most of them are arranged in parallel to their longitudinal axis, fig. 11.

The maximum number of papillae becomes less as the age advances; whereas the average number of papillae may decrease slightly from the juvenile period to the maturity period, but there is hardly any change after maturity.

Discussion.

The size and shape of papillae foliatae of Japanese is not same throughout the tongue. They are large at the middle and toward back part of the tongue and become small in dimension and low in height as they are found in the direction toward the front. The mucous membrane of the papillae of those which are in the front part of the cluster becomes a mere trace of the papilla.

The shape of papillae foliatae of the adults varies, some are in typical definite shape, the others appear as a mere trace having a shallow furrow, and still others are in such a state that they are difficult to separate from the surface of ordinary mucous membrane. These facts are in agreement of

Fig. 11. The sections are cut parallel to the free surface of papillae foliatae. $\times 15$. The material is from a 26 year old female.

what Ebner, and Stahr found in their investigations.

As to the method of determining the number of papillae foliatae whether all the furrows on the lateral side should be counted or not, the opinions of the investigators differ. Ebner for instance states that glands of the mucous around the papillae should be the boundary limit for counting.

On the other hand, Stahr thinks that although there may be no taste buds in the furrow of the front end of the lateral line, this should be taken into account because such cornified papillae should be regarded to have the mechanical function of taste.

In order to carry out the function of taste, the furrows ought to be in perfect order and there should be taste buds. Our investigation shows that if the furrows are not in perfect conditions, there are a lesser number of the taste buds. From this fact, our method of counting the papillae was based on the presence of the taste buds. The author will take another occasion to publish his observations on the number of taste buds.

The average number of papillae foliatae in the tongues of Japanese is 12.1 in the juvenile period, 10.3 at maturity and old age. The most common occurrence was 5 or 6 papillae on each lateral side.

Tuckermann reports that the number of papillae foliatae of Europeans is from 5 to 8, Ebner states from 4-6. The author is not intending to use these figures in contrast with his own findings because their method of counting is different from that of his, besides the materials they used in their investigation were far less in number than his. He shall wait for some other day when more comprehensive studies and data on this problem among Europeans will be published.

Conclusion.

Out of 115 tongues from a new born baby to a 90 year old Japanese, 63 males and 52 females, 230 papillae clusters were taken and examined. The principal results are as follows:

1. The development of the papillae foliatae is irregular. The clear cut demarkation which separates the papilla from the furrow or papillae cluster region from the surrounding tissues is absent.

2. In some cases one papilla may bifurcate into two papillae, and in another case two papillae may unite into one. The shape of papillae foliatae also varies, though many are oblong spindle shaped and they are arranged in parallel to their own longitudinal axis.

3. The size of papillae along the lateral ridge of the tongue is large from the middle toward the root of the tongue, and becomes small toward

the front. Consequently the furrow in between the papillae is deeper toward the back than toward the front.

4. The average number of papillae foliatae per tongue was 10.9. There were more tongues which had 10 or 11 papillae foliatae per tongue than other numbers.

5. The average number of papillae foliatae on one side of the tongue was 5.6. The most predominant cases were 5 papillae on the side, 6 followed next, and 4 and 7 were practically of the same frequency.

6. There was no significant difference in the number of papillae foliatae on each side. Five or six was most common.

7. There were 42.5% of the total in which the number of papillae on each side was same. Five papillae on each side was most numerous and six came next.

8. There was 57.5% in which the number of papillae on each side was different. Cases in which the right lateral side had more papillae than the left side were slightly more numerous than vice-versa. Five papillae on right side and six on the left or six on the right side and five on the left were most numerous.

9. The average number of papillae in the male was 11.2 and that of the female was 10.6. The most predominant cases in the male was 11 papillae and that of the female was 10.

10. The different age groups show different number of papillae foliatae in a whole tongue. The average in the juvenile period was 12.1; in maturity and old age was 10.3. Thirteen papillae were most frequent in the juvenile period and 11 for maturity, and 10 for old age. There is a tendency for the number of papillae to decrease as the age advances.

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