Taste Buds in the Mouse Nasopharynx with Special Reference to the Nasopharyngeal Hiatus

By

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Summary: In the lateral wall of the mouse nasopharynx, 2-6 taste buds were observed on each side. They were located in the area close to the nasopharyngeal hiatus, which was circularly surrounded by the palatopharyngeal eminence, and were embedded in the stratified cuboidal and the stratified squamous types of the intermediate epithelium. It was suggested that the taste buds were related to the reflex mechanism protecting the upper respiratory tract in swallowing, i.e. when the taste buds were stimulated by food and its information was conveyed to the central nervous system, the soft palate was drawn by the levator palati muscle and the palatopharyngeus muscle to close the nasopharyngeal hiatus.

In the extralingual regions, such as the larynx, arytenoid region and esophagus, some investigators have sought the function of the taste buds in the intricate mechanism of swallowing (Johnson et al., 1973; Downing and Lee, 1975; Bradly et al.; 1980; Rodrigo et al., 1980; Stedman et al., 1983; Nakano and Muto, 1986). However, the function of the taste buds in the nasopharynx has been little studied.

Passavant (1869) reported that a ridge, known as the "Passavant’s bar", was formed on the dorsal wall of the pharynx at the level of the soft palate by closure of the "nasopharyngeal hiatus (Wood Jones, 1940)" in ordinary phonation of vocal sound and swallowing. The present authors (Nakano and Muto, 1985) described in the mouse that the palatopharyngeus muscle acted synergically with the levator palati muscle and formed the ridge corresponding to the human Passavant’s bar in swallowing. However, the mechanism why the information of food is conveyed to the central nervous system has been unresolved. This paper reports the distribution of the taste buds in the mouse nasopharynx to discuss their functional role, and is expected to contribute towards a further understanding of the mechanism of swallowing.

Materials and Methods

The materials were the nasopharyngeal regions removed from 20 SMA mice (12 male and 8 female). Light microscopy specimens, aged 0 day, 1 day and 6 months, were fixed in Zenker’s fluid containing 5% acetic acid, decalcified in 6% nitric acid, dehydrated in a graded ethanol series, and embedded in paraffin. They were serially cut into frontal or sagittal sections at a
thickness of 5-7 μm and were applied with hematoxylin and eosin stain.

Scanning electron microscopy specimens, aged from 6 to 12 months, were fixed with 2.5% glutaraldehyde in phosphate buffer, postfixed with 2% osmium tetroxide, immersed in 2% tannic acid, and stained with 2% osmium tetroxide. They were dehydrated in graded ethanol. After replacement with isoamyl acetate and drying at critical point with liquid CO₂, they were coated with gold and observed under a Jeol-U3 scanning electron microscope.

Results

The mouse nasopharynx is a part between the choanae and the "nasopharyngeal hiatus (Wood Jones, 1940)", which is circularly surrounded by the "palatopharyngeal eminence (Nakano and Muto, 1985)" arising from the caudal end of the soft palate and constituting a ridge on the lateral and dorsal walls of the pharynx. The caudal part of the nasopharynx is lined by the "intermediate epithelium (Nakano, 1986)" which occupies the transitional zone between the ciliated columnar epithelium continuing from the nasal cavity and the keratinized stratified squamous one covering the palatopharyngeal eminence (Figs. 1-3). The intermediate epithelium shows gradations ranging from the ciliated

Table 1. The number of taste buds in the mouse nasopharynx.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Age</th>
<th>Right</th>
<th>Left</th>
<th>Total</th>
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<tr>
<td>1</td>
<td>0 day</td>
<td>0</td>
<td>0</td>
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<td>2</td>
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<td>3</td>
<td>1 day</td>
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<tr>
<td>7</td>
<td>6 months</td>
<td>6</td>
<td>2</td>
<td>8</td>
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stratified low-columnar to the stratified cuboidal type, as the epithelium is observed rostro-caudally along the length of the nasopharynx. A well-defined cornified layer is not observed in the intermediate epithelium.

In the newborn mice, the intermediate epithelium is present only in a narrow zone and contains no taste buds (Table. 1). In the adult mice, however, the intermediate epithelium occupies the relatively wide zone extending from the juxtaposition of the Eustachian orifices to the inner edge of the palatopharyngeal eminence and contains 2-6 taste buds on each side (Table. 1). The taste buds are located in the lateral wall of the nasopharynx, near the rostral edge of the nasopharyngeal hiatus (Figs. 1 and 2). Most of the taste buds are found in the stratified cuboidal type of the intermediate epithelium (Figs. 2-4), but a few are seen in the stratified squamous type of the epithelium (Figs. 2 and 5). The taste buds extend through the whole depth of the epithelium from the basement membrane to the surface (Fig. 4). Occasionally, the height of the taste buds is taller than that of the surrounding epithelium (Fig. 5). The taste buds are barrel shaped and consist of two types of cells; supporting cells having lightly stained round nuclei and sensory cells with elongated darkly stained nuclei (Figs. 4 and 5). The apical processes of the supporting cells surround a small opening, the inner taste pore, which leads into a narrow channel. The narrow channel penetrates the epithelium and opens at the outer taste pore (Fig. 5).

In the lateral wall of the nasopharynx, the lamina propria is thin and the submucosa is filled with mixed glands, containing more numerous serous cells than mucous ones (Figs. 1-3). In spite of detailed examining of specimens, no definite relationships between the taste buds and the glandular
openings are detected.

Under the scanning electron microscope, the taste pore is opened in the form of a circular orifice and is approximately 1-1.5 \( \mu m \) in diameter. In most cases, the taste pore is opened on the round knoll slightly elevated above the general level of the surrounding epithelium (Fig. 6). Occasionally, the epithelial cells surrounding the taste pore appear slightly bent down into the pore (Fig. 6a). The epithelial surface surrounding the taste pore has two basic appearances; microvilli and microridges (Fig. 6). The microvilli are short nub-like in form and arranged irregularly. The spaces between them vary within a range of 0.1-1.0 \( \mu m \), but the diameter is fairly constant, 0.1-0.2 \( \mu m \). The microridges consist of fine surface ledge of about 0.1-0.2 \( \mu m \) in width, the same size as the diameter of the microvilli, with spaces of approximately 0.1-0.2 \( \mu m \) between them. The length varies considerably.

Discussion

For the purpose of this study, the limits of the nasopharynx are of special importance. As a result for comparative anatomy of various animals, Wood Jones (1940) used the term “nasopharyngeal hiatus” for the communication between the nasal cavity and the pharynx, i.e. the part above the soft palate and the nasopharyngeal hiatus was regarded as a part of the nasal cavity. Furthermore, Negus (1961) suggested that the term “posterior nasal passage” should be applied to the part. However, the present authors (Nakano and Muto, 1985) defined that the mouse nasopharynx extended from the nasopharyngeal hiatus to the choanae, considering the comparative anatomy.

The taste buds in the nasopharynx have been little studied, in contrast to many literatures concerning those in the tongue, soft palate and epiglottis. Disse (1895), Kallius (1905) and Kolmer (1927) reported that there were the epithelial buds similar to the taste buds in the nasal cavity of some mammalian genera. In the human newborn, Lalonde and Eglitis (1961) found the typical taste buds in the nasal surface of the soft palate. Leela and Kanagasuntheram (1973) described in the macaque monkey and slow lorises that a number of typical taste buds were encountered in the lateral walls at the caudal part of the nasopharynx and occasional ones were seen in the soft palate closer to its free border. In rodents, the present authors (Nakano et al., 1983) first reported that the taste buds were observed in the mouse nasopharynx. Later, Kurihara (1985) reported the presence of the taste buds in the nasopharynx of the Mongolian gerbil, but the distribution was not clear from his figures and description.

Nakano (1986), one of the present authors, reported that the caudal part of the mouse nasopharynx was lined by the “intermediate epithelium”, which occupied the transitional zone between the ciliated columnar epithelium continuing from the nasal cavity and the keratinized stratified squamous one covering the palatopharyngeal eminence. The intermediate epithelium showed gradations ranging from ciliated stratified low-columnar through stratified cuboidal to stratified squamous type (Nakano, 1986). In this study, the taste buds were encountered in the stratified cuboidal and the stratified squamous types of the intermediate epithelium. Leela and Kanagasuntheram (1973) reported that in the macaque monkey the taste buds were observed in the “varying types of epithelia”, while in the slow lorises they were encountered in the “transitional epithelium” similar to that of the urinary bladder. Considered from their morphological similarities, the varying types of epithelia in the macaque monkey and the transitional epithelium in the slow loris appear to
correspond to the intermediate epithelium. According to Kurihara (1985), the taste buds in the Mongolian gerbil were observed in the "transitional type epithelium" and in the "keratinized stratified squamous one" covering the caudal end of the nasopharynx. Although the nature of the transitional type epithelium was not clear from his description, it appears to correspond to the stratified cuboidal type of the intermediate epithelium. Furthermore, Kurihara (1985) speculated that the extension of the keratinized epithelium into the nasopharynx represented a protective response to the environment to which the Mongolian gerbil was exposed, because the keratinized epithelium was more resistance to dryness than the nonkeratinized one. In the mouse, however, the keratinized epithelium did not extend into the nasopharynx. On the other hands, Lalonde and Eglitis (1961) reported in the human newborn that there were the taste buds in the ciliated columnar epithelium lining the dorsal surface of the soft palate. In this study, no taste buds weie encountered in the ciliated columnar epithelium.

The function of the taste buds in the extralingual regions has been the subject of investigation. Kiesow (1902) hypothesized in the human epiglottis that the taste buds were a phylogenetic residue with no functional role. It is unlike that the taste buds in the mouse nasopharynx are a phylogenetic residue, because they developed after birth and were found to be grouped together exclusively in the area close to the nasopharyngeal hiatus. This clustering effect suggests that the taste buds have any functional roles in the upper respiratory tract.

In some mammals, it has been pointed out that the functional relationships between the taste buds and the olfaction can not be ruled out. Hofer (1977, 1978, 1980) and Wöhmann-Repenning (1978) suggested in the Prosimiae that the taste buds in the incisive papilla were functionally related to the olfactory system through the nasopalatine ducts and the vomeronasal organ through the vomeronasal ducts. Furthermore, Ide and Munger (1980) suggested that there was a series of parallels between the chemosensory systems of the taste and the olfaction, i.e. both the taste and the olfaction systems are characterized by an impressive renewal of receptor cells and by the presence of apical cytoplasmic processes of chemosensory cells. In the mouse nasopharynx, however, the taste buds were distributed exclusively in the area close to the nasopharyngeal hiatus and were not observed in th rostral part of the nasopharynx and in the nasal cavity. These findings suggest that the taste buds in the mouse nasopharynx are not responsible for the olfaction.

Some investigators have sought the function of the extralingual taste buds in the intricate mechanism of swallowing. The taste buds in the larynx were considered to mediate the reflex responses of swallowing and apnoea during chemical stimulation of the larynx in the foetus and newborn (Johnson et al., 1973; Downing and Lee, 1975; Bradley et al., 1980; Stedman et al., 1983). Rodrigo et al. (1980) stated in the Cercopithecidae that the taste buds in the rostral part of the esophagus situated in the area close to the pharyngoesophageal sphincter, and were related to gathering information on the characteristics of food as it sliped through the esophagus in order to distent its wall by the pharyngoesophageal sphincter. Furthermore, the present authors (Nakano and Muto, 1986) suggested that the taste buds in the mouse arytenoid region were related to the reflex mechanism protecting the upper respiratory tract in swallowing.
In the previous study (Nakano and Muto, 1985) the present authors reported that the palatopharyngeus muscle encircled the nasopharyngeal hiatus to form the muscular basis of the palatopharyngeal eminence, acted synergically with the levator palati muscle and formed the ridge corresponding to human Passavant's bar in swallowing. In this study, it was observed, that the taste buds in the mouse nasopharynx were located in the area close to the nasopharyngeal hiatus, which was circularly surrounded by the palatopharyngeal eminence. These findings suggest that when the taste buds in the mouse nasopharynx are stimulated by food and its information is conveyed to the central nervous system, the soft palate is drawn by the levator palati muscle and the palatopharyngeal eminence is contracted by the palatopharyngeus muscle to close the nasopharyngeal hiatus.

Some investigators reported in the primates that the taste buds in the plica sublingualis and the soft palate were densely distributed in the juxtaposition to the openings of the salivary glands, and suggested there were any functional relationships between the taste buds and the glands, i.e. chemical substances dissolved in saliva stimulated the activity of the taste buds and accelerated the taste of food (Hofer, 1977; Klein and Schroeder, 1979). In the mouse nasopharynx, however, no definite relationships between the taste buds and the glands were detected.

Acknowledgement

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References

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PLATES
Explanation of Figures

Plate I

Fig. 1. Frontal section of the nasopharynx. A taste bud (arrow) is present in the lateral wall. PP = palatopharyngeus muscle. S = soft palate. O = oral cavity. g = glandular layer. X30.

Fig. 2. Sagittal section of the nasopharynx. Taste buds are found in the stratified cuboidal type (arrows) and in the stratified squamous type (double arrows) of the intermediate epithelium lining the lateral wall. Arrowheads = rostral part of the palatopharyngeal eminence. PP = palatopharyngeus muscle. LP = levator palati muscle. S = soft palate. O = oral cavity. g = glandular layer. X60.

Fig. 3. Sagittal section of the nasopharynx. Taste buds (arrows) are found in the stratified cuboidal type of the intermediate epithelium. g = glandular layer. X120.
Plate II

Fig. 4. A taste bud embedded in the stratified cuboidal type of the intermediate epithelium. X300.

Fig. 5. A taste bud embedded in the stratified squamous type of the intermediate epithelium. X300.

Fig. 6. Scanning electron micrographs showing the taste pore (arrow). The epithelial surface surrounding the taste pore has microvilli and microridges. X10,000.