

Anatomical and morphological aspects of papillae, epithelium, muscles, and glands of rats' tongue: Light, scanning, and transmission electron microscopic study

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Abstract: *Purpose:* The purpose of this paper is to describe the research results of the morphological structure of white laboratory rats' tongue at the macro-, micro-, and ultrastructural levels by scanning, light, and transmission electron microscopy. *Results:* Our results show that the tongue of these rats has a number of unique morphological features that are different from the tongue of other rodents consequently to allow identifying their species-specific features. *Conclusions:* Our findings have shown the features of the tongue structure of white laboratory rats at micro-, macro-, and ultrascopic levels. The data analysis revealed that mucous membrane of the tongue contains a large number of papillae, such as fungiform, filiform, foliate, vallate, and multifilamentary papillae. Each has a different shape, size, and location. The tongue's morphological feature consists of three types of filiform papillae, well-developed foliate and multifilamentary papillae, as well as one large and similar smaller circumvallate papillae. The muscle of the tongue contains a large number of mitochondria of different shapes and sizes. However, we have received data for a complete picture of structure of this organ that will be useful in further experimental and morphological studies of the white laboratory rats.

Keywords: rat, tongue, papillae, microscopy, oral cavity, morphometry

Introduction

In recent years, the number of tongue and oral cavity diseases has been increasing due to the general trend of aging and the deterioration of the somatic status of population, the emergence of new systemic diseases, the ecologically unfavorable situation, occupational factors, and the persistence of harmful habits that negatively affect the oral cavity [1–3]. This factor leads to the investigation of oral cavity under the impact of new negative factors.

In view of the fact that the most of experiments designed to study the impact of various exogenous and endogenous factors on the human body are carried out on animals, the necessity arises for the comparison and the extrapolation of data of morphological features of the animals' organs and human. The knowledge of morphology of the unchanged organ is a key element for performing experimental investigation.

Analysis of the literature has revealed many articles devoted to the study of structural and functional characteristics of the tongue [4, 5]. However, these data are

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fragmented and ungrouped due to the investigation of various tongue structures of different animals [6, 7]. Furthermore, the morphological features of the tongue and papillae vary widely in different species of mammals through the influence of the environment, functional activities, the way of capture and manipulation of the food, swallowing, the vocal modulations of the animals, and the animal care [8–10].

In addition, there is a continuing need for the improvement of obtained data due to the rapid scientific progress and the perfecting of research techniques.

In view of abovementioned statement, there is a need to examine the tongue at all morphological levels and to categorize the obtained data for clear understanding of the organ structure and for further morphological and experimental research of white laboratory rats.

The objective of this paper is to describe the research results of the morphological structure of white laboratory rats' tongue at the macro-, micro-, and ultrastructural levels by scanning, light, and transmission electron microscopy for obtaining more detailed and complete information about the structure and spatial organization of the tongue.

Materials and Methods

The study was conducted on 10 matured male rats. The average weight of the rats was 224.58 ± 5.86 g. Each rat was euthanized by overdose of ether narcosis followed by the study of the specimens: mucous membrane of the dorsal surface and the muscle of the tongue. The rats were kept in vivarium conditions (the vivarium of Medical Institute of Sumy State University). Maintenance of the rats and the experiments were carried out in accordance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1986); Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the Protection of Animals Used for Scientific Purposes; and The General Ethical Principles for Experiments on Animals, which were accepted by the First Bioethics National Congress (Kyiv, 2001).

Histological specimens were stained with hematoxylin and eosin (H&E). The specimens were analyzed using a light microscope "OLYMPUS" with a digital camera (Baumer Optronic Typ: CX 05 with lenses 4, 10×40, and binocular 10). The ultramicroscopic study was performed using a transmission and a scanning electron microscopy (TEM-125K and SEM-106M), manufactured by JCK Selmi (Sumy, Ukraine), with the acceleration voltage of 75–100 kV. The magnified (1,500–13,600) images were processed by the Kappa Image program and with the digital camera Baumer/Optronic Typ: CX 05c.

We had conducted the study with the following parameters: animal weight (AW), the absolute weight of the tongue (AWT), the relative weight of the tongue (RWT), the length of the tongue (LT), the width (WT) and thickness of the tongue (TT), papilla length (PL), diameter of base and apex of papilla (DBP and DAP), diameter of taste bud (DTB), thickness of epithelium (TE), the horny layer thickness of the epithelium (HLTE), lamina propria thickness (LPT), keratinization index (KI), the nuclear–cytoplasmic ratio (NCR) of epithelial cells, diameter of arteriole (DA), diameter of capillary (DC), diameter of venule (DV), arteriole/venular coefficient (AVC), diameter of muscle fiber (DMF), width of endomysium (WE), width of perimysium (WP), diameter of myofibrils (DM), the square of nucleus (SN), the square of mitochondria (SM), the volume of nucleus (VN), and the volume of mitochondria (VM). All statistical analyses were performed using the Statistical Package for Social Science program (SPSS for Windows, version 15.0, SPSS Inc., Chicago, IL, USA).

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Results

The tongue of white laboratory rats is a well-developed muscular organ with length of 28.33 ± 0.705 mm (Table I) that has an elongated shape in the rostro-caudal direction with an extended tip (Fig. 1A). The width in the middle of the back of the tongue is 7.52 ± 0.297 mm and the thickness is 5.52 ± 0.339 mm (Table I). The weight of the tongue is 0.83 ± 0.018 g, whereas the relative weight is only 0.37 ± 0.014 g (Table I). The intermolar prominence is the widest and thick part of the tongue located between the root and body of the tongue. The medial sulcus extends from the tip to the middle of the back of the tongue. The several lingual gland ducts and blind hole are located in the region of root. The fold of mucous membrane – frenulum of tongue – connects the tongue to the floor of the mouth and is located in the middle of area between the tip and the body from the ventral surface of the tongue. The mucous membrane covers the dorsal, ventral, and lateral surfaces of the tongue. It has an uneven surface on the dorsal surface and forms the formations – papillae – which have the same structure but are different in shape and size (Fig. 1B).

The dorsal surface of the tongue is covered by partially keratinized stratified squamous epithelium (Fig. 2A). The lamina propria is located under the epithelial layer and is separated from it by basal membrane. The lamina propria is represented by the loose connective tissue which includes the plurality of vessels and nerves (Fig. 2C).

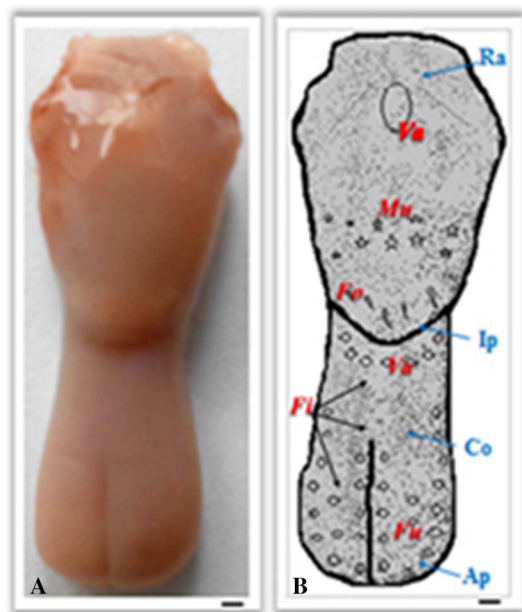


Fig. 1. (A) Overview of the dorsal surface of the tongue of white laboratory rats. Scale bar: 1 mm. (B) Diagram of the tongue: Ap – tip of the tongue, Co – body of the tongue, Ra – root of the tongue, Fi – filiform papillae, Fu – fungiform papillae, Va – circumvallate papillae, Fo – foliate papillae, Mu – multifilamentary papillae, and IP – intermolar prominence

Embedding into the epithelium, the lamina propria forms the primary papillae. Secondary small papillae are located on their surface and are formed a main stroma of the papillae (Fig. 2B). The lamina propria is fused with the underlying connective tissue of the tongue muscles without a sharp boundary.

The thickness of the epithelial layer of lamina propria and the ratio of its layers of different parts of the tongue among the papillae are different. Thus, the thickness of the epithelial layer in the middle of the back of the tongue among the papillae is 248.7 ± 3.41 mm, thickness of lamina propria is 125.67 ± 4.14 μ m, thickness of the corneal layer is 47.07 ± 5.33 μ m, and KI is $18.94 \pm 0.46\%$ (Table II).

The morphometric parameters of microvasculature of the mucous membrane of the tongue are as follows: DA – 16.55 ± 0.36 μ m, DV – 21.73 ± 0.19 μ m, DC – 6.09 ± 0.23 μ m, and AVC – 0.76 ± 0.02 μ m (Table III).

The epithelium consists of four layers: basal, spinosum, granulosum, and corneum (Fig. 2E). The basal layer includes the epithelial cells of prismatic or cubic form, which are perpendicularly arranged to the basal membrane (Fig. 2E). They have an oval hyperchromic nuclei

with one or two nucleoli, well-developed organelles, and the basophilic cytoplasm with NCR ($23.69 \pm 0.501\%$) (Table II). Among the cells of this layer, the large number of mitosis is observed. The spinosum layer consists of several rows of large cells with irregular polygonal shape which are contacted with each other utilizing numerous branches called “spikes” formed by beams of tonofilaments (Fig. 2E). As we approach the granular layer, epithelial cells gradually become elongated and take a parallel location to the surface of epithelium. NCR of epithelial cells of this layer is $16.23 \pm 1.233\%$ (Table II). The granulosum layer (Fig. 2E) is formed by 7–10 rows of cells with large oval form and granular cytoplasm with NCR ($11.79 \pm 0.87\%$) (Table II). The cells contain the hyperchromic round nuclei, a small number of mitochondria, ribosomes, Golgi apparatus, and numerous tonofilaments oriented parallel to the layer of epithelium. Furthermore, numerous granules of two types are identified: (1) large, basophilic, round, unlimited by membrane containing keratohyalin and (2) small, plate keratinosomes. The intercellular spaces are more enlarged against the cells of spinosum layer. As we approach the surface of epithelium, the cells of granulosum layer undergo pronounced changes: they become denser and flat, their organelles and nuclei disappear, cytoplasm becomes denser and is filled with filament, the outer cell membrane becomes thicker. The corneum layer (Fig. 2D) is the most superficial and is formed by flat horny scales that have a thicker outer cell membrane and do not contain nucleus and organelles and they are filled with the keratin filaments embedded in a dense matrix. The horny scales are exfoliated from the surface of epithelium in the outer parts of the layer.

The presence of a large number of papillae, which are different in size, shape, and localization on the dorsal surface of the tongue, was observed under the scanning electron microscope (Fig. 3A). The filiform papillae are arranged at the tip, dorsal, and lateral surfaces of the tongue. They have thin, elongated form with pointed and rounded tips that are densely spaced to each other with height of 368.67 ± 15.96 μ m on the tip of the tongue (Fig. 3A). Their base diameter is 106.81 ± 4.38 μ m. These papillae are covered by keratinized stratified epithelium where the thickness of the stratum corneum is 32.08 ± 1.29 μ m (Table IV).

The fungiform papillae resemble a dome-like structure on the lateral surfaces and medial sulcus of the tongue in an amount of 60–80 (Fig. 3A and 3D). Their height is 204.24 ± 4.52 μ m, the base diameter is 148.94 ± 2.67 μ m,

Table I Organometric parameters of the tongue of white laboratory rats

AW, g	AWT, g	RWT, g	LT, mm	WT, mm	TT, mm
224.58 ± 5.86	0.83 ± 0.02	0.37 ± 0.01	28.33 ± 0.71	7.52 ± 0.29	5.52 ± 0.34

All values are expressed as mean \pm SD ($n=10$)

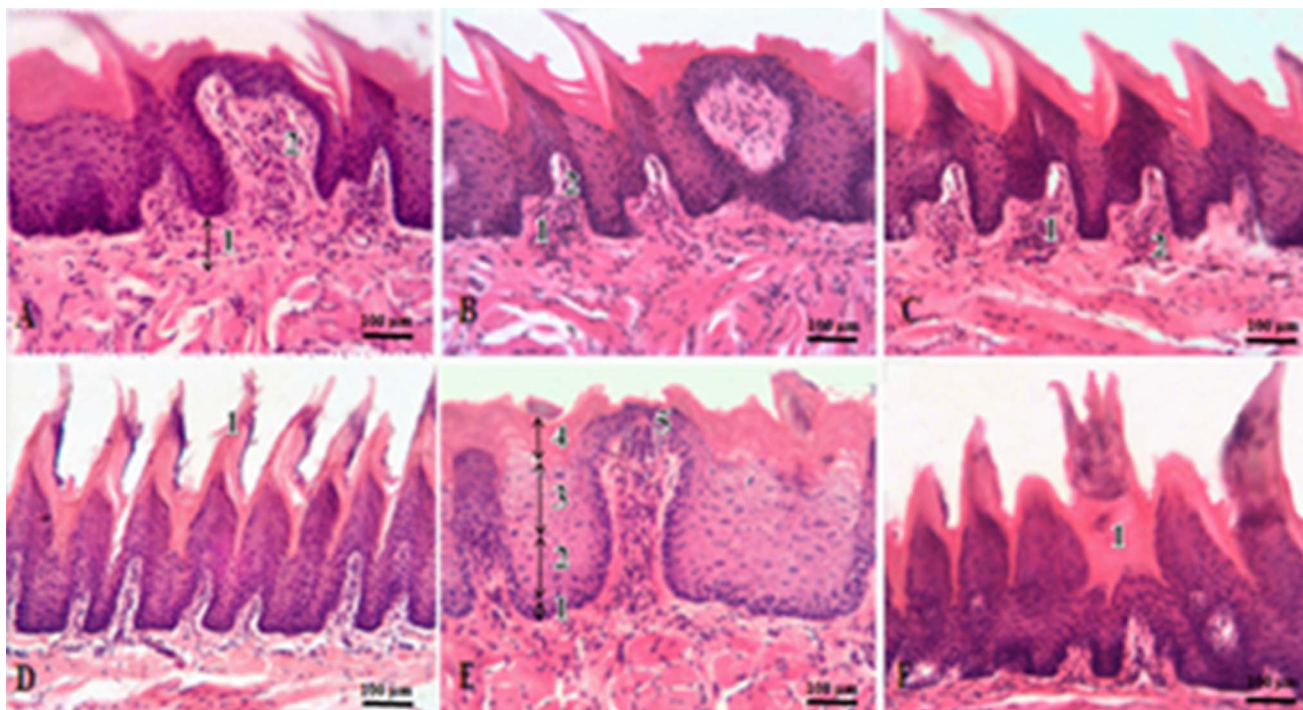


Fig. 2. The sagittal section of the tongue of white laboratory rats. (A) The fungiform and filiform papilla on the tip of the tongue. The lamina propria (1) and the capillaries in secondary connective tissue papillae (2). (B) The filiform and circumvallate papillae of the back of the tongue. The primary (1) and secondary (2) connective tissue papillae. (C) The conical filiform papillae near the root of the tongue. The capillaries in the lamina propria of the tongue (1, 2). (D) The foliate papillae at the intermolar prominence. The desquamated horny scales (1). (E) The circumvallate papillae near the root of tongue. The layer of basal cells (1), the layer of spinosum cells (2), the layer of granulosum cells (3), the corneal layer (4). (F) The multifilamentary papilla. The connective tissue base of papilla (1), the taste bud (5). H&E staining

Table II The morphometric parameters of the mucous membrane of the dorsal surface of the tongue of white laboratory rats

TE, μm	HLTE, μm	LPT, μm	KI, %	NCR ebt	NCR est	NCR egt
248.69 ± 3.41	47.07 ± 5.33	125.67 ± 4.14	18.94 ± 0.46	23.69 ± 0.51	16.23 ± 1.23	11.79 ± 0.87

All values are expressed as mean \pm SD ($n = 10$). ebt: the epithelium of basal layer; est: the epithelium of spinosum layer; egt: the epithelium of granulosum layer

Table III The morphometric parameters of microvasculature of the mucous membrane of the tongue of white laboratory rats

DA, μm	DC, μm	DV, μm	AVC
16.55 ± 0.36	6.09 ± 0.23	21.73 ± 0.19	0.76 ± 0.02

All values are expressed as mean \pm SD ($n = 10$)

and the diameter of the tip is $236.87 \pm 5.82 \mu\text{m}$. A taste bud with diameter of $16.28 \pm 1.77 \mu\text{m}$ is located in the middle of each fungiform papilla. This group of papillae is covered by partially keratinized stratified epithelium where the thickness of the stratum corneum is $12.69 \pm 2.29 \mu\text{m}$ (Table IV).

The filiform papillae have a more remote location from each other (Fig. 3B), a lower height of $323.36 \pm 6.48 \mu\text{m}$, the larger base diameter of $115.37 \pm 2.42 \mu\text{m}$ in the middle of back of the tongue against the previous filiform papillae. The thickness of the stratum corneum is $30.45 \pm 2.41 \mu\text{m}$ on average (Table IV).

The conical filiform papillae are located near the root of the tongue (Fig. 3C). They are arranged on a greater distance from each other than the previous papillae and have a broader base diameter of $120.55 \pm 6.84 \mu\text{m}$ and a narrow tip. Their height is $272.53 \pm 3.85 \mu\text{m}$ and the thickness of the stratum corneum is $24.88 \pm 1.49 \mu\text{m}$.

The circumvallate papillae are located among the conical filiform papillae, and their form resembles the fungiform papillae but smaller in size (Fig. 3C and 3F). They form the circumferential groove around themselves going deep into the mucosa. Their base diameter is $82.19 \pm 3.49 \mu\text{m}$ and the tip diameter is $164.27 \pm 3.54 \mu\text{m}$. The height is $202.71 \pm 2.59 \mu\text{m}$ and the width of the stratum corneum is $12.23 \pm 2.15 \mu\text{m}$. One or two taste buds with diameter of $18.62 \pm 1.49 \mu\text{m}$ are located in the middle of each papilla and the grooves (Table IV).

The intermolar prominence formed by foliate papillae, which are densely arranged to each other and have sharp

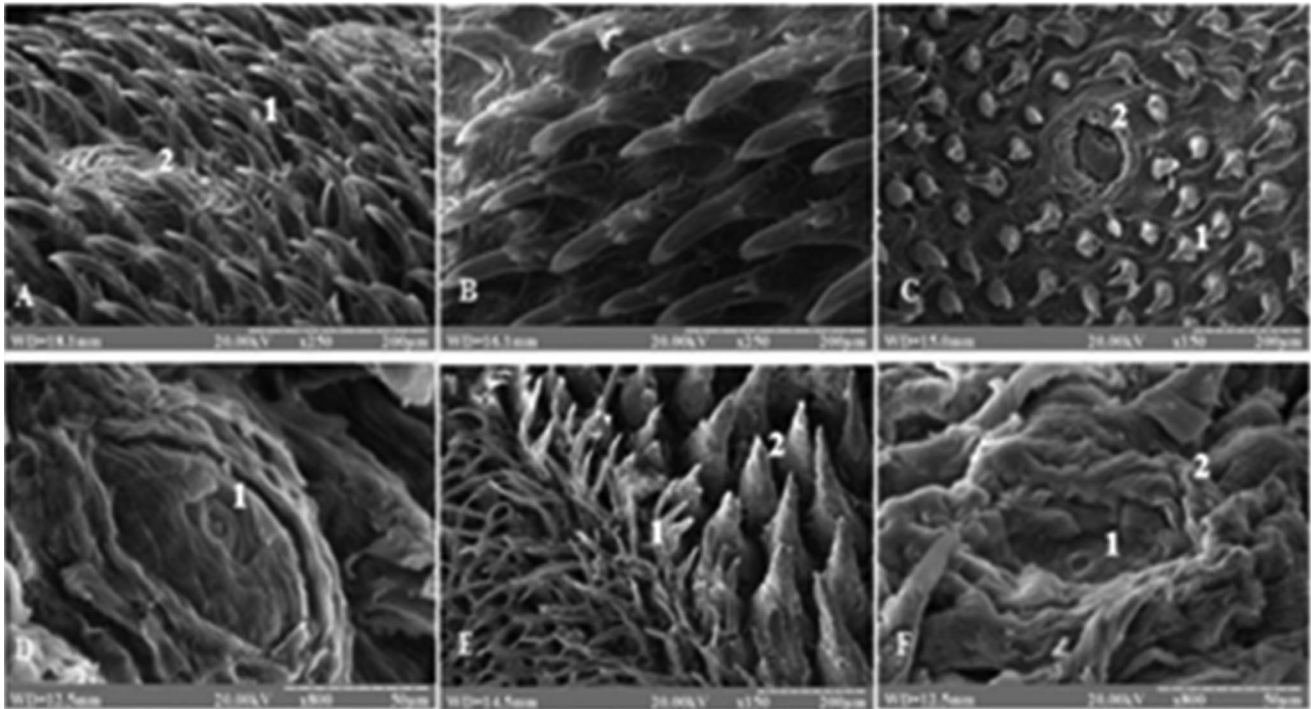


Fig. 3. Scanning electron micrographs of the dorsal surface of the tongue of white laboratory rats. (A) The filiform papillae (1) and fungiform papillae located on the tip of the tongue (2). (B) Filiform papillae on the back of the tongue. (C) The conical filiform papillae (1) and the circumvallate papillae (2) near the root of the tongue. (D) The fungiform papillae arranged on the tip of the tongue. A taste bud (1). (E) The intermolar prominence. The multifilamentary papillae (1) and the foliate papillae (2). (F) The multifilamentary papillae near the root of the tongue. A taste bud (1) and deep groove (2)

Table IV The morphometric parameters of the tongue papillae of white laboratory rats

	PL, μm	DBP, μm	HLTE, μm	DAP, μm	DTB, μm
Filiform papillae on the tip of the tongue	368.67 ± 6.01	106.81 ± 4.38	32.08 ± 1.29		
Filiform papillae on the dorsal of the tongue	323.36 ± 6.48	115.37 ± 2.42	30.45 ± 2.41		
Filiform papillae near the root of the tongue	272.53 ± 3.85	120.55 ± 6.84	24.88 ± 1.49		
Fungiform papillae	204.24 ± 4.52	148.94 ± 2.67	12.69 ± 2.29	236.87 ± 5.82	16.28 ± 1.77
Circumvallate papillae	202.71 ± 2.59	82.19 ± 3.49	12.23 ± 2.15	164.27 ± 3.54	18.62 ± 1.49
Foliate papillae	418.58 ± 6.04	132.43 ± 1.88	28.79 ± 1.18		
Multicore multifilamentary papillae	406.47 ± 4.32	112.58 ± 2.73	7.21 ± 0.37		

All values are expressed as mean \pm SD ($n=10$)

splintered apices (Fig. 3E) in an amount of 170–200, with height of $418.59 \pm 6.04 \mu\text{m}$ and with base diameter of $132.43 \pm 1.882 \mu\text{m}$, is localized between the root and body of the tongue. They are covered by keratinized stratified epithelium where the thickness of the stratum corneum is $28.79 \pm 1.18 \mu\text{m}$ on average (Table IV).

The multifilamentary papillae are located behind the intermolar prominence. They have a common base from which three, four, and sometimes five long and thin filaments depart (Fig. 3E). The diameter of their base is

$112.58 \pm 2.73 \mu\text{m}$, the height is $406.47 \pm 4.32 \mu\text{m}$, and the thickness of the stratum corneum is $7.21 \pm 0.37 \mu\text{m}$ (Table IV).

During the study of intrinsic muscles of the tongue of white laboratory rats, it was found that the tongue is formed by the striated muscle fibers of different directions (Fig. 4A).

The muscle fiber is a multinucleated cell – myosymplast – which is surrounded by the sarcolemma. The basal membrane is adjacent to it exteriorly. Almost the entire volume of the myosymplast is occupied by elongated

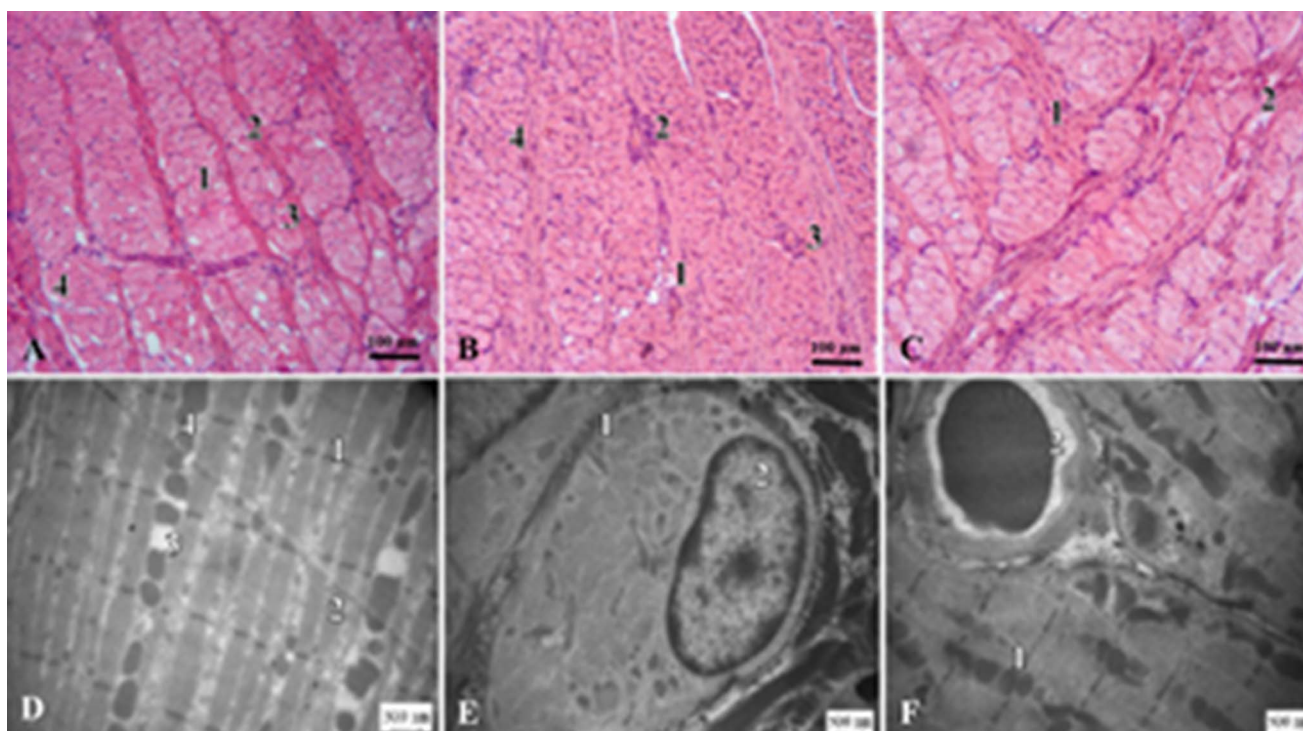


Fig. 4. The frontal (A, C, D, F) and sagittal (B, E) section of the tongue of white laboratory rats. (A) The transverse (1) and longitudinal (2) muscle fibers. The endomysium (3). The perimysium (4). (B) The adipocytes between the muscle fibers (1). The arteriola (2) and capillary (3) of muscle of the tongue. The nuclei of myosmyplast under sarcolemma (4). (C) The transverse muscle fibers (1) and capillary (2) of muscle of the tongue. (D) The sarcomeres of myofibrils of the muscle fibers. The dark Z-line of the sarcomere (1). The dark A-bands of the sarcomere (2). The sarcoplasmic reticulum (3). The mitochondria (4). (E) The muscle fiber. The sarcolemma (1). The nucleus of myosmyplast (2). (F) The muscle fiber. The mitochondria (1) and capillary (2)

myofibrils that are closely adjacent to each other. The diameter of the muscle fiber is $41.29 \pm 2.01 \mu\text{m}$ on average (Table V). The nuclei of elongated and oval shapes are placed under sarcolemma (Fig. 4B).

The outside muscle is covered with a connective tissue – epimysium – which is connected with lamina propria of the tongue without sharp boundary. The fibrous septa are branched from the epimysium into the depth of muscle, and they surround the perimysium (Fig. 4A) whose width is $15.57 \pm 1.25 \mu\text{m}$. Each multinucleated cell of muscle is surrounded by a thinner connective tissue – endomysium – whose width is $7.82 \pm 0.674 \mu\text{m}$ (Table V).

The connective tissue of the tongue includes a large number of vessels and nerves (Fig. 4B and 4C). In this case, DA is $18.94 \pm 0.34 \mu\text{m}$, DV is $23.17 \pm 0.22 \mu\text{m}$, DC is $7.92 \pm 0.53 \mu\text{m}$, and AVC is $0.82 \pm 0.02 \mu\text{m}$ (Table VI). The light and large fat cells of an irregular shape – adipocytes – are arranged between the muscle fibers (Fig. 4B).

The muscle fibers of tongue have a classic cell-symplastic structure that was observed during the ultramicroscopic study. Myofibrils are arranged in the sarcoplasm along its length and occupied the central part (Fig. 4D). The width of each myofibril is $548.53 \pm 10.11 \text{ nm}$ (Table V). They are visualized as filaments along the longitudinal sections. These filaments tightly adjoin each other and consist of two types of myofilaments namely thin and thick myofilaments. The thick myofilaments are localized in the middle of the sarcomere. The thin myofilaments are attached to the telophragma, dark Z-line (Fig. 4D), and are partially located between thick myofilaments. The intersections of thin and thick myofilaments are darker and form the A-bands (Fig. 4D). The light I-bands are formed in places where the thin and thick filaments are not intersected. A region in the middle of an A-band is lighter and consists of only thick myosin myofilaments. The cross-striation of all muscle fibers is formed through the abovementioned

Table V The morphometric parameters of the muscle tongue of white laboratory rats

DMF, μm	WE, μm	WP, μm	DM, nm	SN, μm^2	VN, μm^3	SM, μm^2	VM, μm^3
41.29 ± 2.01	7.82 ± 0.67	15.57 ± 1.25	548.53 ± 10.11	16.47 ± 1.47	40.18 ± 2.36	0.29 ± 0.02	0.15 ± 0.01

All values are expressed as mean \pm SD ($n=10$)

Table VI | The morphometric parameters of the vessel microcirculatory bloodstream of the muscle tongue of white laboratory rats

DA, μm	DC, μm	DV, μm	AVC
18.94 ± 0.34	7.92 ± 0.53	23.17 ± 0.22	0.82 ± 0.02

All values are expressed as mean \pm SD ($n=10$)

ordered alternation of the dark and light bands of myofibril. The nuclei of muscle fibers are exactly located on the periphery and they include the 1–2 nucleoli, the evenly distributed chromatin and are characterized by the moderate electron density (Fig. 4E). The nucleus area of myosymplast is $16.47 \pm 1.47 \mu\text{m}^2$ and the nucleus volume of myosymplast is $40.18 \pm 2.36 \mu\text{m}^3$ (Table V). The mitochondria are mostly of cylindrical shape and are located between the myofibrils on the short distance from each other, and their average area and volume are $0.29 \pm 1.47 \mu\text{m}^2$ and $0.15 \pm 0.01 \mu\text{m}^3$, respectively (Table V). The inner membrane of mitochondria forms numerous cristae which almost completely cross the organelle. Each mitochondrion is filled by the matrix where the spherical and ovoid granules are located in addition to the cristae (Fig. 4F).

The sarcoplasmic reticulum of muscle fibers is represented by a complex of tubes and cisterns (Fig. 4D) which

form around each myofibril a similarity of the cuff, and is connected with the cavities of “cuff” around the neighboring fibrils. The Golgi complex, the single vesicles of different sizes, and a few of lysosomes, which are located on the periphery of muscle symplast, are also observed among the membrane structures in sarcoplasm.

The serous (Fig. 5A) and mucous glands (Fig. 5A and 5B), the excretory ducts of which are opened to the surface epithelium between the multicore and foliate papillae, are placed between muscle fiber bundles under the mucous membrane of the root of the tongue. The terminal sections of the mucous glands consist of mucous cells (Fig. 5E) which have a light large cytoplasm and are placed near the base of cell under the cell membrane of flattened shape as well have a developed granular endoplasmic reticulum and secretory granules of low and medium electron density. The acinus of serous glands is represented by the serous cells (Fig. 5D) which are located on the basal membrane as well have pyramidal shape, the eosinophilic cytoplasm with a basal nucleus displacement and the granules with high electron density. The terminal secretory sections distally pass into the narrow glandular tubules which in turn form the excretory ducts.

Preferably, the mixed protein–mucous glands are localized in the anterior area of the tongue. Their

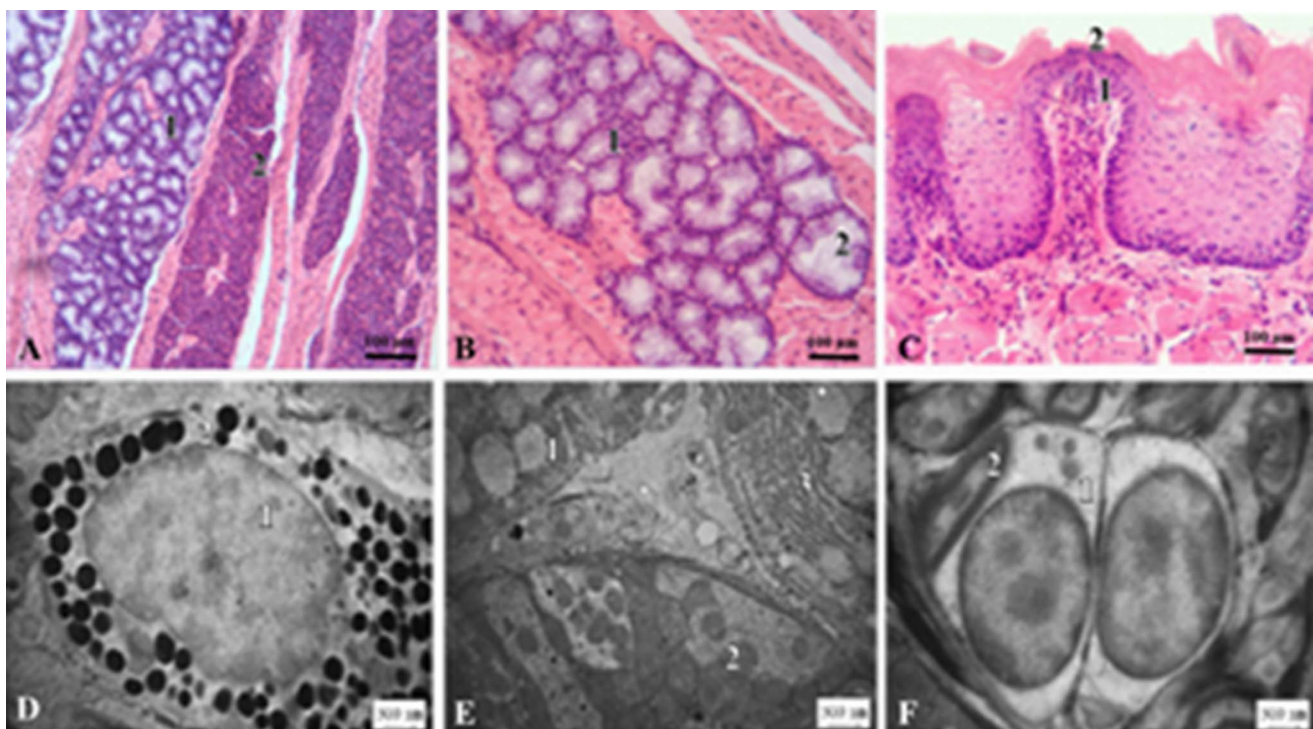


Fig. 5. | The glands (A, B, D, E) and the taste bud (C, F) of the tongue of white laboratory rats. (A) The mucous (1) and serous (2) glands of root of the tongue. (B) The terminal sections (1) of the mucous glands of the tongue. The secretion (2) of the mucous glands of the tongue. (C) The taste and supporting cells (1) of the taste bud (2) of the circumvallate papilla of the tongue. (D) The nucleus (1) and the granules with high electron density (2) of the serous cells of the protein acinus. (E) The secretion granules of the mucous cells of acinus of low (1) and middle electron density (2). The granular endoplasmic reticulum of the mucous cells (3). (F) The taste buds (1) and the non-myelinated nerve fiber (2) of the taste bud of the circumvallate papilla

excretory ducts are opened on the bottom surface of the tongue along its mucous membrane.

The taste buds are represented by the dense cluster of 40–60 cells which include the support, basal, and actual gustatory cells (Fig. 5C). The gustatory (sensory) cells are the narrow, light, high prismatic, with a light nucleus, well-developed organelles, and the beam of thick microvillus on the apical surface. The endings of the unmyelinated nerve fibers are attached to the lateral surface of cell membrane of the gustatory cells (Fig. 5F).

Discussion

The results of this study supplement the description of the topography, ultramicroscopic structure of papillae, dorsal surface, and muscles of the tongue of white laboratory rats. The morphology of the tongue of white laboratory rats is substantially similar to the tongue structure of previously studied mammals. However, the results show that the tongue of these animals has a number of uniquely morphological features which are different from the tongue of other rodents consequently to allow identifying their species-specific features.

The tongue of white laboratory rats has an oblong shape in the rostro-caudal direction and has an expanded tip. The tongue of the blind mole rats also has an oblong shape but at the same time it narrows toward the rounded tip [11]. In case of studied animal, the length of tongue is 28.33 ± 0.71 mm, and the width and thickness of back of the tongue is 7.52 ± 0.29 mm and 5.52 ± 0.34 mm, respectively. The length of the tongue of mole rat is 17–18 mm and the greatest thickness is 5–6 mm, while the weight of mole rat and white laboratory rat is practically equal and is 200–220 g. The tongue of the bank vole is oblong with an expanded tip and has the length of 11–13.5 mm. It has a narrow back of width 2 mm [12] in the medial part. The filiform papillae of white laboratory rats are densely distributed on the dorsal surface of tongue while the distance between them is increased from the tip of the tongue to its root and the papillae become lower and wider. The filiform papillae of blind mole rat, shrew, and bank vole are also densely distributed on the dorsal surface of tongue, but at the same time they are gradually increased in size from the tip to the root of the tongue [11–13].

The fungiform papillae in an amount of 60–80 are located among filiform papillae on the tip of the tongue of white laboratory rats. They have a rounded shape and resemble a mushroom cap or dome. The fungiform papillae in guinea pig, bank vole, and flying squirrel are located on tip between filiform papillae and lateral surfaces of tongue body. Along with this, the papillae near the edges of the tongue are smaller than in the central part [12, 14, 15]. The fungiform papillae are found only on the arch of the tongue in the shrew. The taste bud is located in the middle of every papilla.

The conical filiform papillae of white laboratory rats have the smaller length and are located on the back near the root on the long distance from each other than the previous filiform papillae. These papillae are the highest and numerous as well and they have the widest basis among all filiform papillae of the tongue of bank vole [12]. In case of the blind mole rat, the conical filiform papillae are long, thin, have irregular shape, pointed, and are represented by large quantity [11].

The medial sulcus is of different sizes and is a typical specific feature of the tongue of many rodents [12, 16]. Thus, the medial sulcus is absent in guinea pig that was described by Kobayashi [14], but it has structural features in mouse, bank vole, and American beavers [12, 17–19]. This study showed that the medial sulcus is developed and extended from the tip to the middle of the back of the tongue in white laboratory rat.

The number of circumvallate papillae among the rodents is widely different. The one large papilla surrounded by roll is located on the posterior part on the medial line of tongue not only in white laboratory rat but also in mouse and bank vole [12, 17]. Flying squirrel, shrew, and American beavers have three circumvallate papillae [10, 15, 18–21]. The two circumvallate papillae on both sides of posterior part of tongue are located in blind mole rat and guinea pig [11, 14, 20].

The roll around the papilla is formed by thick fold of mucous membrane of the tongue that is caused by the formation of deep circumferential groove between body of papilla and roll that was described in this study. This observation is similar to the studies of Iwasaki et al. [18] and Jackowiak [22].

During the study of the back of the tongue, the circumvallate papillae which are similar to the large circumvallate papillae have been found between the conical filiform papillae. These papillae form the circumferential groove around themselves and have one or two taste buds. However not all rodents have these papillae [22–24].

The intermolar prominence is formed by massive and wide foliate papillae in an amount of 120. The prominence was described by many authors as a lingual prominence formed by the longer filiform and perpendicularly directed papillae [11]. Iwasaki et al. [18] reported that the intermolar prominence in rats is formed by the large conical papillae.

In addition, we found that the large numbers of special papillae are located behind the intermolar prominence in the caudal regions that were previously described in the single works [18, 23]. They have a common base from which three, four, and sometimes five long filaments depart, so they were named as multifilamentary papillae. They are located between foliate and circumvallate papillae. Iwasaki et al. [18] have noted that the filiform papillae are located behind the intermolar prominence, the apices of which are branched to form several slender twigs.

It has been found that one and sometimes several taste buds, which have a lot of nerve fibers (nerve endings), are located in each fungiform papilla and circumvallate papilla. This finding highlights the importance of the rats to have the developed taste and sensory organs including tongue due to the food habits, their behavior, and nocturnal nature [22].

The own muscles are presented by one muscle which consists of muscle fibers oriented in the longitudinal, transverse, and vertical directions. Each of muscle fibers is surrounded by perimysium. The outside muscle is covered by epimysium that is connected with lamina propria of the tongue without sharp boundary. These results are similar to the studies of Al-Serwi and Ghoneim [25] and Fujita and Sato [26]. The muscle of tongue of the rat has the developed mitochondrial apparatus. Mitochondria are located between myofibrils in large quantities of small distance from each other placed under sarcolemma around the nuclei of myosin in the skeletal muscles.

Conclusions

Our findings have shown the features of the tongue structure of white laboratory rats at micro-, macro-, and ultrascopic levels. The data analysis revealed that mucous membrane of the tongue contains a large number of papillae, such as fungiform, filiform, foliate, vallate, and multifilamentary papillae. Each of them has a different shape, size, and location. The tongue's morphological feature consists of three types of filiform papillae, well-developed foliate and multifilamentary papillae, as well as one large and similar smaller circumvallate papillae. The muscle of the tongue contains a large number of mitochondria of different shapes and sizes. However, we have received data for a complete picture of structure of this organ that will be useful in further experimental and morphological studies of the white laboratory rats.

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