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The taxonomic implication of different morphological systems in bats

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Abstract: The structures of the upper tongue surface and male accessory glands in bats are described. Using differences in the structures of these morphological systems, *Hypsugo* was separated as an independent genus; generic validity of the subgenera *Amblyotus* and *Eptesicus* has been confirmed and the necessity of forming a new family, Miniopteridae has been pointed out. The autor agrees with the opinion of researches who have placed Rhinolophidae and Hipposideridae into one family, Rhinolophidae.

Regarding higher taxa as natural adaptive types (Krasilov 1973, 1987), we believe that each taxon should possess a group of characteristic features shared by all specimens of this taxon. Evaluation of morphological peculiarities of different organs has led us to the conclusion that each organ reflects, in its own way, evolution of the organism as a whole and we can find, in the organism, features more or less valuable for taxonomic identification. This paper deals with studies of the morphology of male accessory glands and upper tongue surface in bats and considers possibilities of using these structures for systematic identification of bats.

There are descriptions of the morphology of male accessory glands in some species of bats (Matthews 1941; Mokkapati & Dominic 1977; Murthy 1979, 1981, etc) but these data have not been used as a taxonomic criterion. Peculiarities of tongue morphology have been already used in the systematics of bats (Griffiths 1982) and have evoked great discussion (Smith & Hood 1984).

Therefore, accumulation of evidence on external tongue structure in different families of bats appears to be very important. Determination of stability in certain features of the tongue structure in taxa of different levels allows us to define the systematic level on which they may be used.

Materials and Methods

Specimens for the present study were collected from the territory of the Soviet Fat East; besides, collections of bats from the Zoological Institute of the USSR Academy of Sciences were used.

The external tongue structure was studied in 26 species of bats (the tuimbeT of specimens examined is given in brackets): *Rhinolophus ferrumequinum* (2), *Rh. hipposideros* (1), *Hipposideros armiger* (1), *H,* sp. (2), *Myotis myotis* (2), *M. daubentoni* (15), *M. capaccinii*(10), *M. nattereri*(10), *M. brandti*(20), *M. ikonnikovi(\0), M.frater* (10), *Plecotus auritus* (15), *Barbastella barbastellus* (2), *B. leucomelas (1), Nyctalus leisleri(l), N. noctula(3), Pipistrellus kuhli{2), P. pipistrellus (2), P. nathusii* (2), *P. savii* (15), *Eptesicus nilssoni* (5), *E. serotinus* (1), *Vespertilio murinus* (5), *V. superans* (15), *Miniopterus schreibersi* (10), *Murina aurata* (1), *M. leucogaster* (15). Macromorphology of male accessory glands was studied in 30 species: *M. myotis* (1), *M. blythi* (2), *M. dasycneme* (1), *M. daubentoni* (11), *M. capaccinii* (4), *M. nattereri* (6), *M, brandti* (8), *M. ikonnikovi*(3), *M.frater*(2), *P. auritus*(2), B. *barbastellus*(3), 5. *leucomelas*(1), N. *leisleri(l), N. noctula{2), N. lasiopterus*(1), P. *kuhli(2), P. pipistrellus* (2), P. *nathusii* (1), P. savi"/ (5), E. *nilssoni* (5), £. *bobrinskii* (2), £. *serotinus* (2), E. ftoffae (2), £. *nasutus* (1), K *murinus* (5), K *superans* (4), *Otonycteris hemprichi* (1), M. *schreibersi* (2), M. *aurata (I), M. leucogaster* (17).

I examined mainly adult males caught in the mating period when genital glands are of maximal size (2—3 times bigger than in bats sampled in other periods). Besides, in some species bats younger than a month were also examined.

The following glands were studied: the prostate (prostata), seminal vesicles (vesiculae seminales), ampullary glands (glandulae vesiculares), and Cowper's glands (glandulae bulbo-urethrales). (Fig. 1).

In the studies of male accessory glands I used either bats fixed in alcohol or fesh animals, killed just before dissection. Male accessory glands of all the bats examined are situated under the urinary blader (omitted in the drawings).

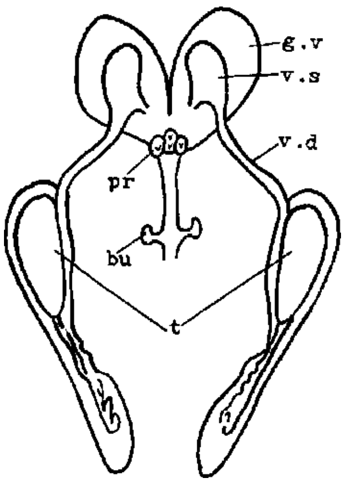
For the studies of the external surface of the tongue, alcohol-preserved material was used. For better identification of different types of pappilae, the tongue surface was stained before examination.

Description

GENERAL OUTLINE OF MALE ACCESSORY GLANDS

Myotis. Nine species belonging to four subgenera of this genus were examined (Ellerman & Morrison-Scott, 1951). Slightly differing in size and proportions, all of them have genital glands of the same morphological type. (Fig. 2a). The prostate is very small, its upper lobes embrace the neck of the bladder. Seminal vesicles, lying directly on ampullary glands, are connected with them by

Fig. 1. Morphology of internal male genitalia in *Myotis nattereri:* t, testis; bu, Cowper's gland; pr, prostate; v.d., vas deferens; v.s., seminal vesicles; g.v., ampullary glands.



small ducts. The vas deferens starts from the lower part of the seminal vesicle. A pair of Cowper's glands is oval in shape, their narrow ducts enter the urethra at the root of the penis.

Plecotus. One species was examined. The prostate lying under the bladder is relatively large and almost completely covering the seminal vesicles (Fig. 2b). Ampullary glands are absent. The vas deferens starts from the upper part of the seminal vesicle. Cowper's glands are oval in shape.

Barbastella. Both species of this genus were examined. Their prostate consists of two parts situated one under the other (Fig. 2c). The lower part of the prostate is two times smaller than the upper one. Seminal vesicles lie under the prostate. Ampullary glands are absent. The ducts of Cowper's glands enter the urethra at the root of the penis.

Nyctalus. External morphology of genital glands was studied in three species. The small prostate is located under the bladder. In these species, seminal vesicles are the biggest among the accessory glands (Fig. 2b). Ampullary glands are absent. The vas deferens starts from the upper part of the seminal vesicle. Cowper's glands are round in shape.

Pipistrellus. Four species of this genus were examined, viz., *P. pipistrellus, P. nathusii, P. kuhli* and *P. savii.* The prostate of the first three species is not large (Fig. 2e). Seminal vesicles are the largest. The vas deferens starts from the middle of the seminal vesicle. Ampullary glands are located under the prostate between seminal vesicles, slightly overlying them. A similar structure of male accessory glands is characteristic also of *P. ceylonicus* (Murthy, 1981). In *P.* sovHthe prostate is the largest and heartlike in shape. (Fig. 2f). It covers almost completely the seminal vesicles and ampullary glands which lie under it. These glands merge with their lower ends in pairs forming almost a complete unity. The

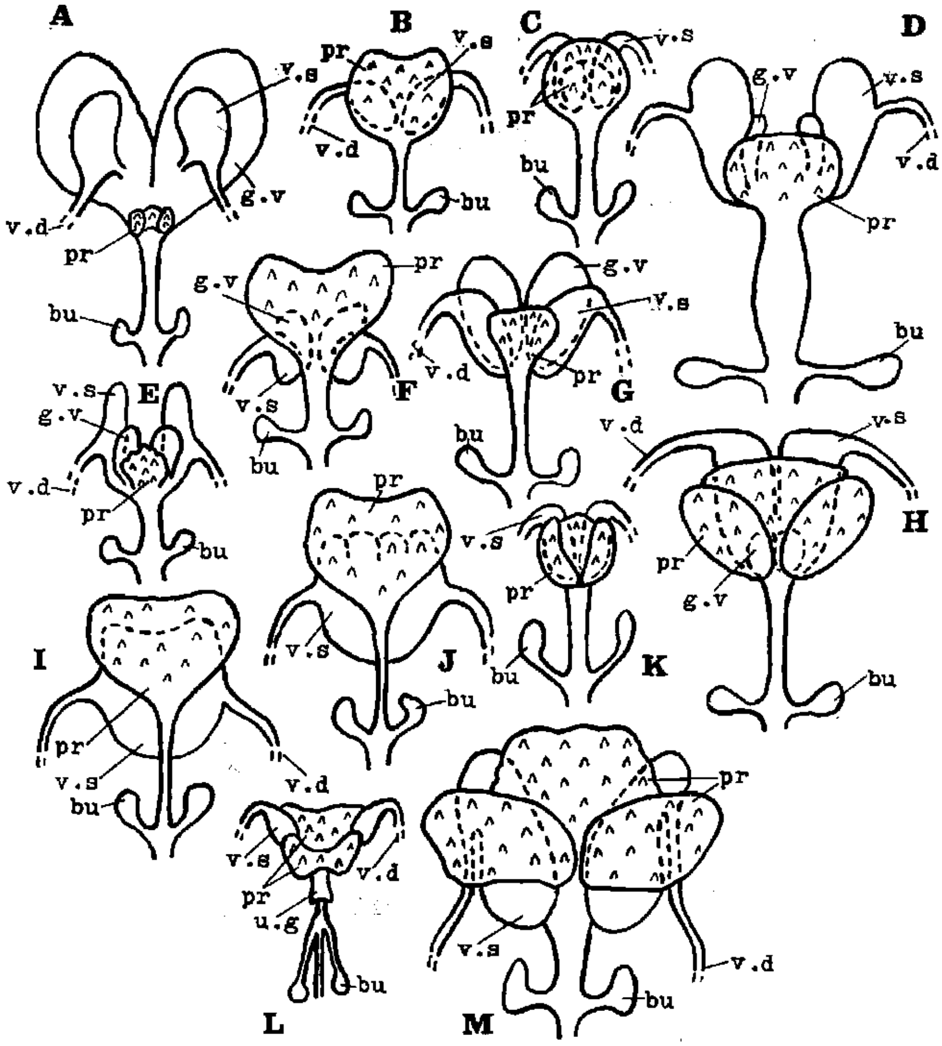


Fig. 2. Morphology of accessory glands in male bats: A, *Myotis brandii, M. ikonnikovi, M. nattered, M. blythi, M. myotis, M. dasycneme, M. daubentoni, M. capaccinii;* B, *Plecotus auritus;* C, *Barbastello barbastelli^, B. leuçomelas;* D, *Nyctalus leisleri, N. noctula, N. lasiopterus;* E, *Pipistrelli^ pipistrelli, P. nathusii, P. kuhli;* F, *P. savii;* G, *Eptesicus nilssoni, E. bobrinskii;* H, *E. serotinus, E. bottae, E. nasutus;* I, *Vespertilio murinus;* J, *V. superans;* K, *Otonycteris hemprichi;* L, *Miniopterus schreibersi;* M, *Murino aurata, M. leucogaster.* Other explanations as for Fig. 1.

vas deferens starts from the upper part of the seminal vesicle. Cowper's glands in all the species examined are situated at the root of the penis.

Eptesicus. In the subgenus *Amblyotus,* represented by two species, *E. nilssoni* and *E. bobrinskii,* the prostate is small and undivided (Fig. 2g). In the mating period, the ampullary glands situated under the seminal vesicles grow the largest. Seminal vesicles lie under the prostate over the ampullary glands. The vas defens starts from the upper part of the seminal vesicle. In the subgenus *Eptesicus,* three species of which were examined *(E. serotinus, E. bottae* and *E. nasutus),* the prostate is large and consists of three lobes (Fig. 2h). The upper lobes cover the neck of the bladder from above. Under the prostate there are large seminal vesicles, small ampullary glands lie under them. The vas deferens starts from the upper lobe of the seminal vesicle. Morphology of Cowper's glands is similar to that of the previously described genus.

Vespertilio. Both species constituting this genus were examined. They have a large prostate (Fig. 2i, j). Seminal vesicles and ampullary glands are merged into a single gland. The fact that this gland was formed by merging of four glands is especially clearly seen in *V. superans* (Fig. 2j). In this species, complete merging in the upper part of the gland has not taken place as yet. The vas deferens starts from the middle of the gland. Cowper's glands, like in the above-examined genera, lie at the root of the penis where they are connected with urethra by small ducts.

Otonycteris. Only one species was examined. Its prostate consists of three lobes (Fig. 2k). The roots of the upper lobes cover the neck of the bladder from above. Seminal vesicles are situated under the prostate. Ampullary glands are absent.

Miniopterus. One species, *M. schreibersi,* was examined. Its relatively large prostate appears to be formed of two parts (Fig. 21). One of them embraces ringwise the neck of the bladder covering seminal vesicles from above. The other one is situated betwen the seminal vesicles. Ampullary glands are absent. The vas deferens starts from the upper part of the seminal vesicle. The urethral gland surrounds the upper part of the urethral canal. Ovoid Cowper's glands are situated at the root of the penis. Their long narrow ducts are connected with the urethral canal just after the bulge formed by the urethral gland. Two further species of this genus, *M. minor* and *M. dasythrix,* are known to have similar structure of male accessory glands (Mathews, 1941).

Murina. Large and small tube-nosed bats belonging to this genus have similar morphology of male accessory glands. The prostate is rather large and consists of three lobes (Fig. 2m). Two lobes are situated from above, their tops covering the neck of the bladder. The lobular structure of the prostate is especially clearly seen on the upper lobe. Large seminal vesicles lie under the prostate; they have a peculiar curve in their upper part. Cowper's glands are situated at the root of the penis, under the rectum. These pair glands are oval-shaped, yellow-orange in colour.

STRUCTURE OF THE TONGUE

AH species of bats examined have three types of papillae on the mucous membrane of the tongue, viz., filiform papillae *(papillae filiformes),* fungiform papillae *(papillae fungiformes)* and circumvallatae papillae *(papillae circumvalattae).* The filiform apillae are distributed all over the upper tongue surface. They are very small and conical in the anterior portion of the tongue. In the middle and at the root of the tongue, they have the form of petals and are much larger. The ungiform papillae are sparse in the medial and anterior portions of the tongue. All genera examined have two circumvalette papillae in the pre-root portion of the tongue.

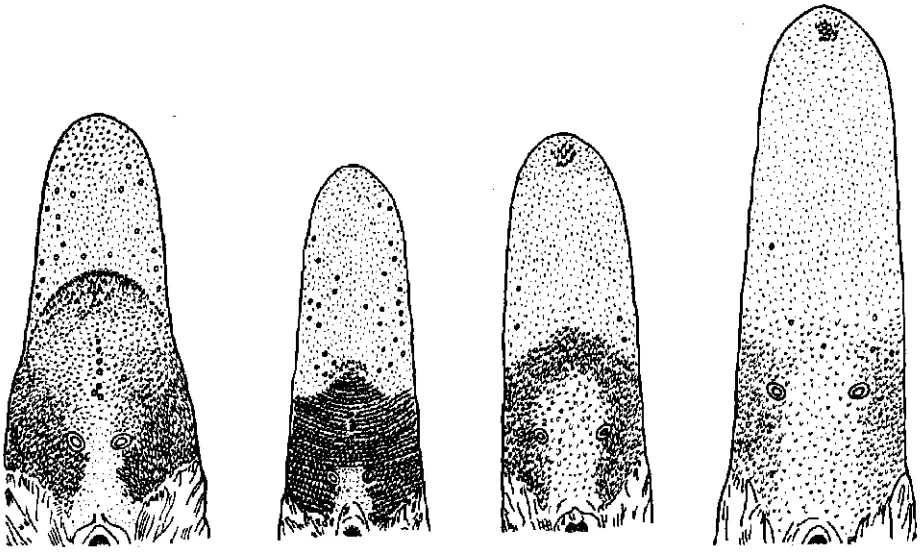


Fig. 3. Different types of structure of the upper tongue surface in bats. A, *N. noctula;* B. *M. schreibersi;* C, *R. ferrumequinum;* D, *H. armiger.*

Representatives of the family Vespertilionidae have a well-developed cushion *(torus linguae).* Here the filiform papillae are larger, and in the anterior region of the cushion they turn their tops forward to the tip of the tongue. Towards the root of the tongue their direction changes. The distance between the circumvalette papillae is no more than 1—2 diameters of the papillae (Fig. 3a). The species *M. schreibersi* is clearly distinguished from all the species of the family Vespertilionidae examined by the distribution of large filiform papillae. In this species, the filiform papillae in the middle and pre-root part of the tongue are distributed in even lines, which produces the impression of continuous ridges (Fig. 3b).

The external structure of the tongue of horseshoe bats and leafnosed bats has very much in common. Unlike the species of the family Vespertilionidae they have no noticeble cushion *(torus linguae),* although the filiform papillae on most of the tongue are thicker than those on the tip. All the representatives of the genera *Rhinolophus* and *Hipposideros* examined have a spot with large filiform papillae on the tip of the tongue (Fig. 3c, d). The distance between the circumvalette papillae is no less than 2—3 diameters of the papillae.

Discussion

The data obtained show, on the one hand, the specifity of macromorphology of male accessory glands for each of the examined genus except the genera *Pipistrellus* and *Eptesicus* and, on the other, complete uniformity of the external morphology of male accessory glands within the genus.

P. savii is distinguished from the species of the genus *Pipistrellus* examined by the external morphology of male accessory glands. But considering other characters, the position of this species in the system appears rather doubtful. Various forms of this species have been related to different species and even to different genera because P^2 in the upper jaw is absent. A. P. Kuzjakin found, in the Soviet Far East, a population of *P. savii* comprising specimens with P^2 developed in various degrees. This allowed Kuzjakin (1944, 1950) to unite all these forms (*Vesperugo caucasicus, Amblyotus tauricus, A. velox, Eptesicus alashanicus* and others) in one species, *Vespertilio savii.* Basing on some common features of this species and the genus *Eptesicus,* Kuzjakin united pipistrelles, serotines and particoloured bats in one genus *Vespertilio.* But such union has not been supported by systematists (Ellerman & Morrison-Scott, 1951; Strelkov, 1963; Wallin, 1969, etc.) and most of them have andered to the traditional point of view on genera, placing *P. savii* in the genus *Pipistrellus.*

Taking into consideration that many features of *P. savii* distinguish this species distinctly from the general outline of the morphology of pipistrelles and place it tentatively in the genus *Pipistrellus,* Strelkov (1963, p. 182) wrote: *"Further studies may give grounds for distinguishing P. savii in an independent subgenus or genus."* Wallin (1969) referred *P. savii* to the subgenus *Hypsugo* including (Kolenati 1856) both *maurus* Blasius 1853 (= *savii* Bonaparte 1837) and *krasheninnikowii* (Eversmann 1853), the latter being synonymous with *Vespertilio murinus* Linnaeus, 1758 (Ognev 1928).

At the same time, those morphological features (structure of skull, dentition), according to which *P. savii* has been placed in one or another genus, as well as a number of generative features such as the unique structure of the male sex organ (penis), T-shaped baculum with widening at the end, are evidently more taxonomically significant than Wallin believed when he insisted on separating *P. savii* in an independent subgenus. All these features, together with the peculiar morphology of male accessory glands, allow us to distinguish *P. savii* from the species of the genus *Pipistrellus* and from the species of closely related *Eptesicus* and *Vespertilio.* I believe (Tiunov 1986) that morphological isolation of *P. savii* is a sufficient ground for establishing an independent genus, *Hypsugo.* Basing on some other characters, Horacek and Hanak (1986) have recently come to the same conclusion.

A similar situation is observed in the genus Eptesicus, the examined species of which are divided now into two subgenera viz., *Amblyotus* and *Eptesicus.* These species groups had been described as independent genera (Ognev 1928). I have found that these groups are strictly distinguished by the external morphology of male accessory glands, and consider this a sufficient ground to join the opinion of S. I. Ognev on the necessity of establishing two independent genera, *Amblyotus* Kolenati, 1858 and *Eptesicus* Rafinesque, 1920.

Thus, macromorphology of male accessory glands may be a good systematic character in the family Vespertilionidae for grouping related species into genera.

We can judge from our results that data on the morphology of the tongue may be used for characterizing families, but we have not yet examined enough representatives of different families to be completely sure of that. But noting that the genus *Miniopterus* considerably differs in the morphology of dentition (Mein & Tupinier 1977; van der Merwe 1985), the structure of spermatozoa (Breed & Inns 1985) as well as in many important embryological characteristics (Gopalakrishna & Chari 1983), the difference found in the morphology of the tongue is an additional argument in favour of separating the genus *Miniopterus* from the family Vespertilionidae and establishing for it a new family, Miniopteridae. We must also point out the appearance of some new elements in the morphology of male accessory glands in *M. schreibersi,* comparing with other representatives of the family Vespertilionidae. These elements include the change of place where Cowper's glands enter the urethra, and the presence of urethral glands.

There is no agreement of opinion concerning leaf-nosed bats of the Old World and horseshoe bats. Some authors have united them in the family Rhinolophidae (Ellerman & Morrison-Scott 1951; Wallin 1969), others have divised them into two families, Rhinolophidae and Hipposideridae. (Miller 1907; Sokolov 1973). Uniform tongue structure in representatives of subfamilies Rhinolophinae and Hipposideridae confirms the opinion of those authors who have united them in one family, Rhinolophidae.

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