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Comparative Study of the Skeleton of the Hyoid Apparatus in Some Bat Species

Badania porównawcze szkieletu aparatu gnykowego u niektórych gatunków nietoperzy

[With 20 Figs.]

I. Introduction 15
II. Material and methods 15
III. Description of the investigated material 16
IV. Comparative review of the skeleton of the hyoid apparatus in the investigated bat species 21
V. Discussion and conclusions 22
VI. Summary 23
References 23
Streszczenie 23

I. INTRODUCTION

This work is a continuation of investigations concerning the structure of the skeleton of the hyoid apparatus of small mammals (Romankowowa, 1962).

A detailed investigation of the hyoid region in bats was carried out by Sprague (1943). He studied 23 American species of the *Megachiroptera* and 22 species of the *Microchiroptera*.

The skeleton of the hyoid apparatus in bats is composed of a centrally located basihyal and of two pairs of horns: *cornu anterior et cornu posterior* (thyrohyal). The aim of this work is a comparative study of the skeleton of the hyoid apparatus in Polish species of bats.

II. MATERIAL AND METHODS

Rhinolophus hipposideros specimens come from the collections of Prof. Dr. Kazimierz Kowalski, the remaining part of the material was given to me by Prof. Dr. Wacław Skuratowicz and mgr Bronisław Wołoszyn. I wish to convey my sincere thanks for facilitating my access to the investigational material.

The following species were studied: 8 specimens of *Rhinolophus hipposideros*

(Bechstein, 1800) of the *Rhinolophidae*, 3 *Myotis myotis* (Borkhausen, 1797), 2 *Myotis mystacinus* (Kuhl, 1819), 1 *Myotis dasycneme* (Boie, 1825), 3 *Myotis daubentoni* (Kuhl, 1819), 4 *Eptesicus serotinus* (Schreber, 1774), 2 *Nyctalus noctula* (Schreber, 1774), 2 *Pipistrellus pipistrellus* (Schreber, 1774), 5 *Plecotus auritus* (Linnaeus, 1758) of the *Vespertilionidae*.

31 specimens were investigated in total. Preparation was the basic method used for investigation. The staining of bones with alizarin was used in an auxiliary manner.

III. DESCRIPTION OF INVESTIGATED MATERIAL

Rhinolophus hipposideros (Bechstein, 1800), Figs. 1, 14

Basihyal. The central part of the bone is spherical, cranially strongly vaulted; a broad, flat process with a shallow triangular incision protrudes caudally. There is a complete lack of a boundary-line between the basihyal and the element that follows. The thyrohyal is flattened and slightly curved. With the basihyal it embraces the larynx in the shape of an arc. It is slightly broadened near the supposed border-line with the basihyal, becomes narrower in the medial region, while its terminal extremity is broader, resembling a small shovel with cut down edges. The cornu anterior is composed of elongated trabecular osseous elements joined together by means of chondroid insertions that are sometimes asymmetric. It has the shape of an elongated S. The intracranial extremity is larger, becoming narrower and more slender when approaching the basihyal. The hypophyal is phalangeal, its free end sharply terminated end curving slightly towards the basihyal and connected with it by means of a delicate ligament. The ceratohyal is more than twice as long as the hypohyal, bacilliform, thickening slightly in the distal direction. The stylohyal is the longest element of the horn, and has a complicated sculpture. About $^1/_4$ of the bones are bacilliform with a slightly thicker intrahyoid extremity. The distal part of the bone is flattened and cristae are formed on the lateral borders. The bone is arched and broadens on approaching to the place of insertion on the skull. In the intracranial part the stylohyal is chondroid and calcification appears only in the marginal part the element.

Myotis myotis (Borkhausen, 1797), Figs. 2, 8, 15

The basihyal is massive, bent in the shape of a horseshoe on the side of the cranial surface. The central region of the bone is inflated, discoidally vaulted on the ventral side, with a deep incision on the caudal side. The terminal extremities of the bone are craniocaudally flattened and connected with the thyrohyal by means of a chondroid insertion. The length of the thyrohyal corresponds to the height of the basihyal

horseshoe. The medial part of this element is a prism with concave margins broadening the bone terminally. The cornu anterior is composed of three elements — two osseous ones with a chondroid insertion between them. It is elongated and S-shaped. The osseous part, directed towards the cranium, is slightly twisted in the long axis, a little convex near the bulla tympanica where it broadens. The osseous sector, directed towards the basihyal is small, flat and elliptic.

Myotis mystacinus (K u h l, 1819), Figs. 3, 9, 16

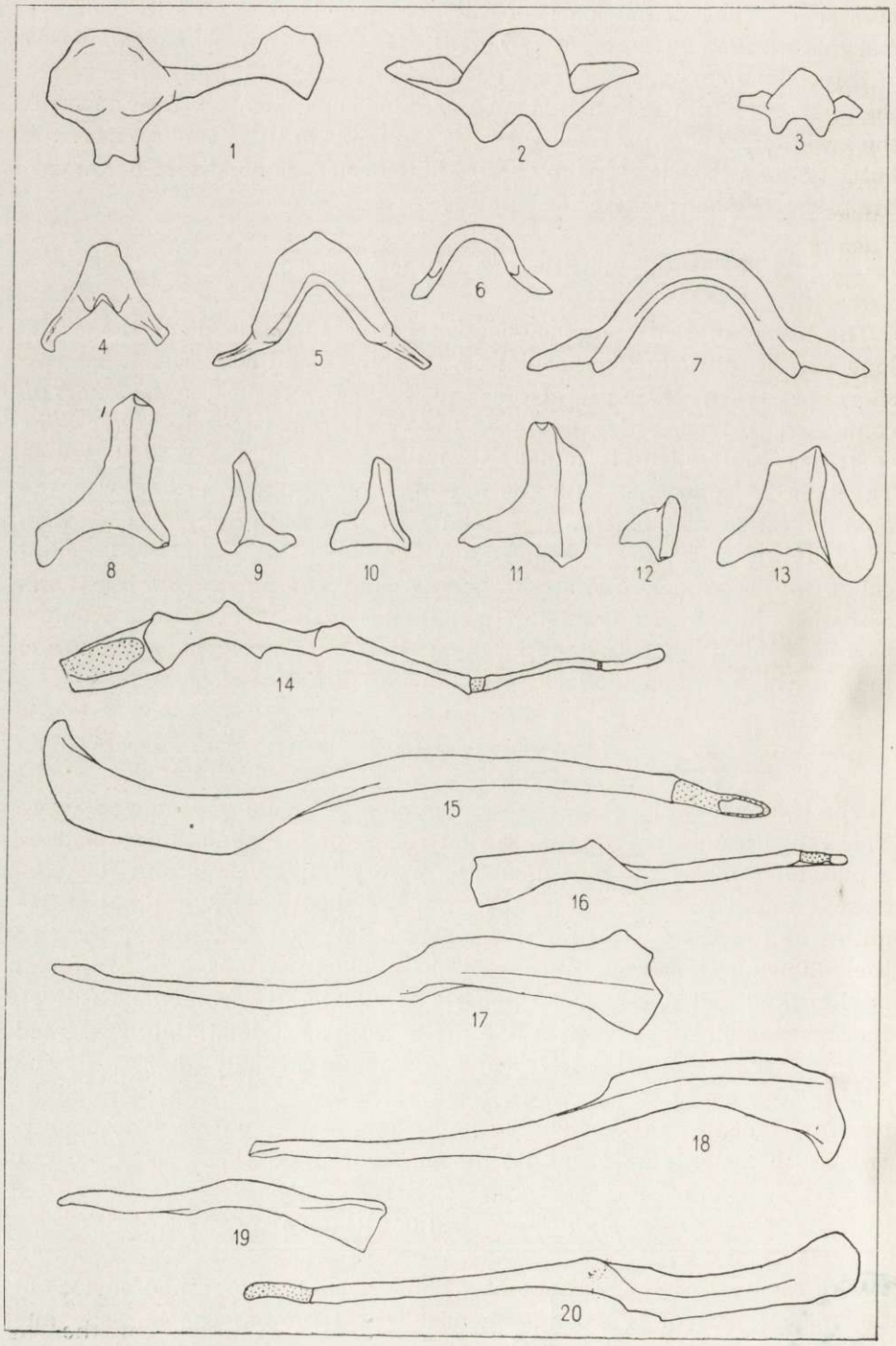
The basihyal, of a horseshoe shape, is situated perpendicularly to the long axis of the body. The medial part is convex and discform. It has two short processes, far apart from each other, on the caudal margin, connected by means of a depressed line. The cranial margin of the bone is steeply vaulted, the terminal extremities are craniocaudally flattened. The bone is connected with the aid of a chondroid insertion with the next investigated element. The axial part of the thyrohyal is a prism with slightly concave surfaces, from which issues laterocaudally an elongated flat process. Cornu anterior is twisted in its long axis, flattened and S-shaped. In the intracranial region this element is broader, becoming narrower on approaching the basihyal. It is terminated by a chondroid rod, in which two small flat ossifications can be noticed.

Myotis dasycneme (B o i e, 1825)

The basihyal is placed in the same manner as in the preceding species. The ventrocranial part of the medial region of the bone is occupied by a platelet forming the half of a disc. Two relatively long and flat processes, rounded at the ends, issue from it caudally. The terminal extremities of the basihyal are craniocaudally flattened and connected with the following element by means of chondroid insertions. The thyrohyal is elongated and massive and departs caudolaterally from the basihyal. Its construction is in the shape of a prism, with a caudolaterally elongated margin. The terminal surface of the bone is strongly depressed, and slightly concave laterally. The cornu anterior is composed of a single osseous element and a relatively long chondroid epiphysis. The bone is twisted in the long axis and has the shape of an S.

Myotis daubentoni (K u h l, 1819)

The basihyal is in the shape of a horseshoe. On the cranial surface of the medial part of the bone a hemispherical process can be seen, the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ventral surface is vaulted discoidally, there are two cone-like nodes on the caudal surface, separated from each other by a deep triangular incision. Two flattened arms of the horseshoe issue in a dorsocaudal direction from the medial part. On the lateral margins of the arms triangular flat cristae are situated, with terminal extremities obliquely cut; they are connected with the following elements by means of chondroid insertions. The thyrohyal is composed of three concave surfaces placed near each other along their long axes; it is relatively long and the proximal end is narrower than the distal one. The medial margin is slightly concave, the lateroventral and terminal ones being deeply concave. The cornu anterior is in a laterocaudal position in relation to the basihyal. It is composed of a broader elongated segment directed towards the cranium, of a chondroid insertion and of a small, phalanx-shaped part, directed hyoidally and terminated by a chondroid flattened element.

Eptesicus serotinus (Schreber, 1774), Figs. 5, 11, 18

The basihyal is trabecular. The ventral part of the bone is discoidally convex, vaulted in the shape of an acute arch from the cranial side. The dorsal surface is concave. Two shovel-like arms, flattened craniocaudally, with obliquely cut terminal extremities, issue from the medial part. The thyrohyal is placed laterocaudally in relation to the basihyal. The structure of the medial part of the bone resembles an elongated prism, the terminal part of the lateral margin forming a long gradually narrowing process, rounded at the end. The cornu anterior is a single bone, elongated, flat and slightly twisted in its long axis. It has the shape of an S and its part situated in the direction of the cranium is twice broader than the remaining slender part.

EXPLANATION OF FIGURES

Skeleton of the hyoid apparatus.

1 — Basihyal and the left thyrohyal of *Rh. hipposideros*, ventral view.

2—7 — Basihyal: 2 — *M. myotis*, ventrocranial view. 3 — *M. mystacinus*, ventrocranial view. 4 — *P. auritus*, ventrocranial view. 5 — *E. serotinus*, ventrocaudal view. 6 — *P. pipistrellus*, ventrocaudal view. 7 — *N. noctula*, ventrocaudal view.

8—13 — Thyrohyal: 8 — *M. myotis*, caudoventral view. 9 — *M. mystacinus*, 10 — *P. auritus*. 11 — *E. serotinus*. 12 — *P. pipistrellus*. 13 — *N. noctula*.

14—20 — Cornu anterior: 14 — *Rh. hipposideros*. 15 — *M. myotis*. 16 — *M. mystacinus*. 17 — *P. auritus*. 18 — *E. serotinus*. 19 — *P. pipistrellus*. 20 — *N. noctula*.

Nyctalus noctula (Schreber, 1774), Figs. 7, 13, 20

The central part of the basihyal is a trabecula bent in the shape of an arc, its convex part being cranial directed. The trabecula ends have two genicular protuberances from which issue dorsocaudally two processes flattened along the long axis, becoming narrower when nearing the terminal extremities. The terminal ends of the basihyal are connected by means of ligaments with the thyrohyal. The thyrohyal is composed of three concave surfaces approaching each other along the long axes. The paramedial and dorsal margins are convex, the retroaxial and terminal margins are concave. Cornu anterior is composed of a single flattened bone, resembling an elongated interrogation mark. Half of the bone is slender and directed intrahyoidally, the remainder is twice as broad. On both ends of the bone are chondroid elements *(epiphyses)*.

Pipistrellus pipistrellus (Schreber, 1774), Figs. 6, 12, 19

The basihyal is a trabecula craniocaudally flattened, placed transversally to the long axis of the body, bent in the shape of an arc and directed cranially. The terminal extremities are depressed in an obtuse angle in the dorsal direction. There are thickenings in the depressions. The terminal ends are sharply cut and the space between the basihyal and the thyrohyal is filled with cartilage. The thyrohyal is massive, the medial part of the bone has the shape of a prism and the ventral margin forms a trapezoidal platelet. The cornu anterior is composed of a single bone terminated by chondroid epiphyses. It is slightly undulating in the long axis, convex in the region of the *bulla tympanica*, flattened and of an S-like shape.

Plecotus auritus (Linnaeus, 1758)

The basihyal is convex in the medial part of the bone, from the ventral side, depressed from the dorsal side and triangular. The apex of the triangle is folded towards the dorsal side. The caudal surface of this part of the bone is shallowly depressed. From the central part of the hyoid bone issue at an acute angle elongated processes, cranio-caudally flattened, cut obliquely on their terminal extremities, connected by means of chondroid insertions with the next element. The thyrohyal is built of two perpendicularly situated osseous platelets, broad at the terminal end and narrowing considerably in the proximal direction. Cornu anterior, in the shape of an S, is flattened and twisted in the long axis. The part directed towards the cranium is broader, the remainder of the bone being slender and narrow.

IV. COMPARATIVE REVIEW OF THE SKELETON OF THE HYOID APPARATUS IN THE INVESTIGATED BAT SPECIES

In the investigated group of bats distinct differences appear between representatives of the *Vespertilionidae* family and the species belonging to the *Rhinolophidae* family. In the *Rhinolophus*, the thyrohyal adheres to the basihyal and in the *Vespertilionidae* both these bones are connected by means of a cartilage. In the *Rhinolophus* the thyrohyal is flattened bilaterally and has smooth sides, bent in the shape of an arc, while in the investigated *Vespertilionidae* they are composed of three surfaces nearing each other on the paracentral line. In the *Rhinolophus* the cornu anterior is composed of phalanxes, in the *Vespertilionidae* — of separate osseous elements, terminated in the part directed towards the basihyal by a chondroid elongated rod in which, in the *Myotis sp.*, a small flat bonelet is developed. The basihyal in its medial part represents two types of structure in the investigated bats. In *Rhinolophus, Myotis sp.* and *Plecotus*, this part is thickened, with a vaulted cranial margin, the caudal margin is provided with two nodes. In *Nyctalus, Pipistrellus* and *Eptesicus* the osseous trabecula is depressed in the shape of an arc in the cranial direction.

In the structure of the basihyal as well as in that of the remaining elements of the skeleton of the hyoid apparatus in the investigated bats visible differences arise, permitting to distinguish separate genera and species. Thus in the *Rhinolophus* the medial part of the basihyal is relatively broad, flat on the side of the dorsal surface, convexedly vaulted on the ventral one. *Margo anterior* resembles in outline a hemispherical arc. In species of the *Vespertilionidae* family the medial region of the basihyal is thickened, the ventral surface slightly convex and the dorsal one somewhat concave. The *margo cranialis* of *Myotis myotis* has the outline of a hemispherical arc, it is in the shape of a segmental arc in *Myotis daubentoni*, of a low, flattened acute arc in *Myotis dasycneme* and of a highly vaulted acute arc, with an apex outwardly folded into the dorsal side in *Plecotus auritus*. In the structure and development of the processes situated on the *margo caudalis* certain differences also arise. In *Nyctalus*, *Eptesicus* and *Pipistrellus* the paracentral region of the basihyal is trabecular, arcuately depressed at a nearly right angle, in the cranial direction. In *Nyctalus* the bone is the largest and the smallest in the *Pipistrellus*.

In the structure and length of the cornu anterior differences also arise. The degree of twisting in the long axis and the vaulting in the region of the *bulla tympanica* vary. Cornu anterior in all investigated bats is connected by a ligament with the basihyal.

V. DISCUSSION AND CONCLUSIONS

The structure of the cervical region in small mammals is a problem deserving attention and requiring detailed investigation, as appears from the work of S p r a g u e (1943) and my own results. The hyoid apparatus of bats of the *Microchiroptera* subspecies underwent a far reaching modification. Investigations of the anatomical structure of the larynx, carried out by E l i a s (1907) became an indication for the studying of the ultrasonic orientation of bats. M ö h r e s (1952) stated the differences in emitted sounds and the manner of sound production in *Vespertilionidae* and *Rhinolophidae*. P o c o c k (1917) found a correlation between the reduction of cornu anterior and the increase in voice production in some *Felidae*. It might be inferred that this correlation takes also place in both of the investigated bat families. In *Rhinolophus*, the cornu antorior is composed of several osseous elements movably assembled; in the *Vespertilionidae* it is reduced to a single bone.

B ö k e r (1937) correlated the shape of the snout of *Macrochiroptera* and *Microchiroptera* with the kind of their food. This opinion does not seem to be correct. The visual orientation of the *Macrochiroptera* and the ultrasonic orientation of *Microchiroptera*, which have been stated, lead to the supposition that sound production can be a modelling factor.

On summing up the investigational results the following conclusions can be reached:

1. The skeleton of the hyoid apparatus in the investigated bats is a highly specialised structure.

2. In the investigated *Vespertilionidae* and *Rhinolophus* a division, in accordance with the systematic division, into two structural types of the hyoid apparatus skeleton takes place.

3. The paramedial region of the hyoid bone in the investigated bat species is developed according to two basic structural types. The first type comprises the *Nyctalus, Eptesicus* and *Pipistrellus*, the second one — the *Rhinolophus, Plecotus* and *Myotis*.

4. The skeleton of the hyoid apparatus in each of the investigated species is developed in a characteristic manner, owing to which its structure can be used as an index in the determination of osseous remnants.

5. The division of the hyoid apparatus skeleton into structural types coincides with data for the types of the ultrasonic orientation of bats. This allows to infer that voice production is the main factor influencing the shape of the hyoid bone.

VI. SUMMARY

31 specimens of *Rhinolophus, Myotis, Eptesicus, Nyctalus, Pipistrellus* and *Plecotus* species were investigated. The skeleton of the hyoid apparatus of bats is a highly specialised structure. Differences in the structure of the hyoid apparatus of *Rhinolophus* and of that of representatives of the investigated *Vespertilionidae* representatives were stated. These differences are in accordance with data for the ultrasonic orientation in these species of bats. A certain resemblance between the structure of the medial region of the hyoid bone of the *Rhinolophus* and that of the investigated part of the *Vespertilionidae* was ascertained.

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STRESZCZENIE

Szkielet aparatu gnykowego u nietoperzy jest strukturą wysoce wyspecjalizowaną. Przebadano 31 okazów należących do rodzajów *Rhinolophus, Myotis, Eptesicus, Nyctalus, Pipistrellus, Plecotus*. Stwierdzono różnice w budowie aparatu gnykowego między *Rhinolophus* a badanymi przedstawicielami *Vespertilionidae*. Różnice te pokrywają się z danymi o orientacji ultradźwiękowej tych gatunków nietoperzy. Poza tym stwierdzono pewne podobieństwo budowy centralnej okolicy kości gnykowej u *Rhinolophus* i *Vespertilionidae*.

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