MORPHOLOGICAL ELEMENTS FOR A KEY TO SUBGENERA OF THE GENUS *BOMBUS* LATREILLE *s.l.* PRESENT IN ITALY

G. BOLCHI, F. INTOPPA [1], M.G. PIAZZA [1]

Istituto di Entomologia agraria, Università degli Studi, Milano, Italy – [1] Istituto Sperimentale per la Zoologia Agraria, Sezione di Apicoltura, Roma, Italy

INTRODUCTION

The number of species of the genus *Bombus* recorded in Italy up to the moment is 33, according to a recent list by INTOPPA *et al.* (1995). This work has been prompted by the expediency of drawing up a dichotomic key bringing these species together, and is based on the revision and evaluation of the diagnostic characteristics considered in the principal works published up to the present by Authors concerned with this topic. These are listed in the bibliography given. In these studies, in the description of subgenera and species and in the setting out of keys, as far as queens and workers are concerned, certain characteristics of the head have been taken as having greater discriminatory weight; then come, in this order, the colour pattern of the body hairs, certain details of the legs and of the last gastral sternites. For the males, on the other hand, greatest attention has been paid to the shape of the genitalia.

For our part, we have chosen to redescribe the morphology of the females' head through objective recognition of each of the Italian species, which belong to the 13 subgenera established by RICHARDS (1968), whose systemation we have adhered to.

The material studied is made up partly of specimens taken personally, partly from museum collections and partly of those made available by courtesy of specialists in the field.

DESCRIPTION OF THE MORPHOLOGICAL STUDY

Up to now, various elements have been used by the Authors quoted in order to describe the *Bombus'* head; these comprise absolute measurements and proportions of measurements, the shape of certain parts, the markings of the surface (tubercles, grooves, ridges, punctures). In these descriptions differences of opinion are to be found, and deficiencies, and even the terminology used is not uniform. Very often there is no precise indication as to how the measurements under consideration have been taken, which means that such measurements cannot be regarded as comparable.

For this reason, in a more detailed study to follow this preliminary presentation, we propose a critical revision of every parameter and a standardisation of the terms used.

For the moment we only deal with the characteristics whose evaluation may be considered certain and which, moreover, are sufficient for the separation of the different groups of species. These parameters are considered and commented on singly.

DIMENSIONS OF THE HEAD

The first of the dimensional characteristics is the proportion of the width to the length of the head, which measurements correspond, respectively, to the greatest distance between the external margins of the

compound eyes (width) and the distance between the vertex and the central point of the anterior margin of the clypeus (length). The relationship between these measurements makes up the cephalic index (KRÜGER, 1920) on the basis of which the subgenera may be divided thus:

– stenocephalic head = cephalic index 79-89 (fig. 1a): *Megabombus, Mendacibombus, (Mucidobombus), Rhodobombus*

– dolycocephalic head = cephalic index 90-93 (fig. 1b): *Alpinobombus, (Mucidobombus), Subterraneobombus, Thoracobombus*

– brachycephalic head = cephalic index 94-98 (fig. 1c): *Confusibombus, Kallobombus, Melanobombus, (Pyrobombus)*

– platycephalic head = cephalic index 100-106 (fig. 1d): *Alpigenobombus, Bombus s.s., (Pyrobombus)*

COMPOUND EYES

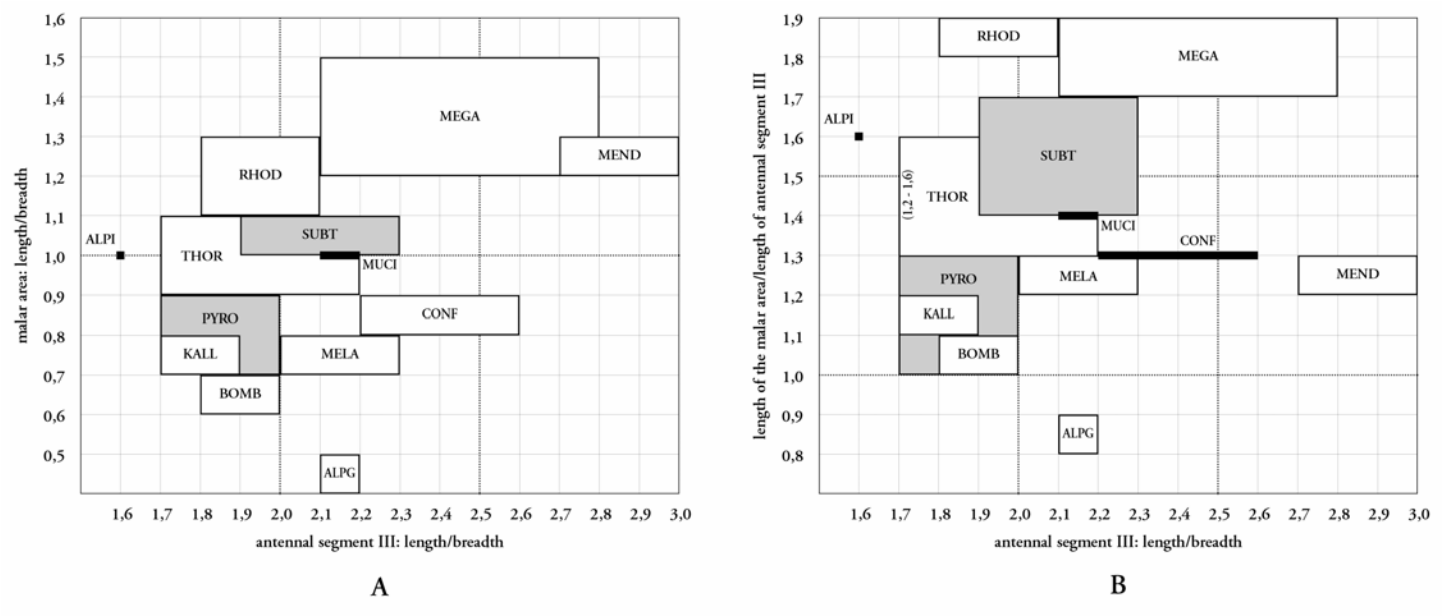
The slant of the longitudinal axis of the compound eye in respect of the mandibular articulation, a characteristic featuring in certain keys published hitherto, permits the separation between the sections Odontobombus (axis towards the condyle or below it, fig. 2) and Anodontobombus (axis towards the abductor swelling, fig. 3) which, moreover, are clearly distinguishable by characteristics from the other parts of the body, in particular the structure of the mesobasitarsus.

MALAR AREA

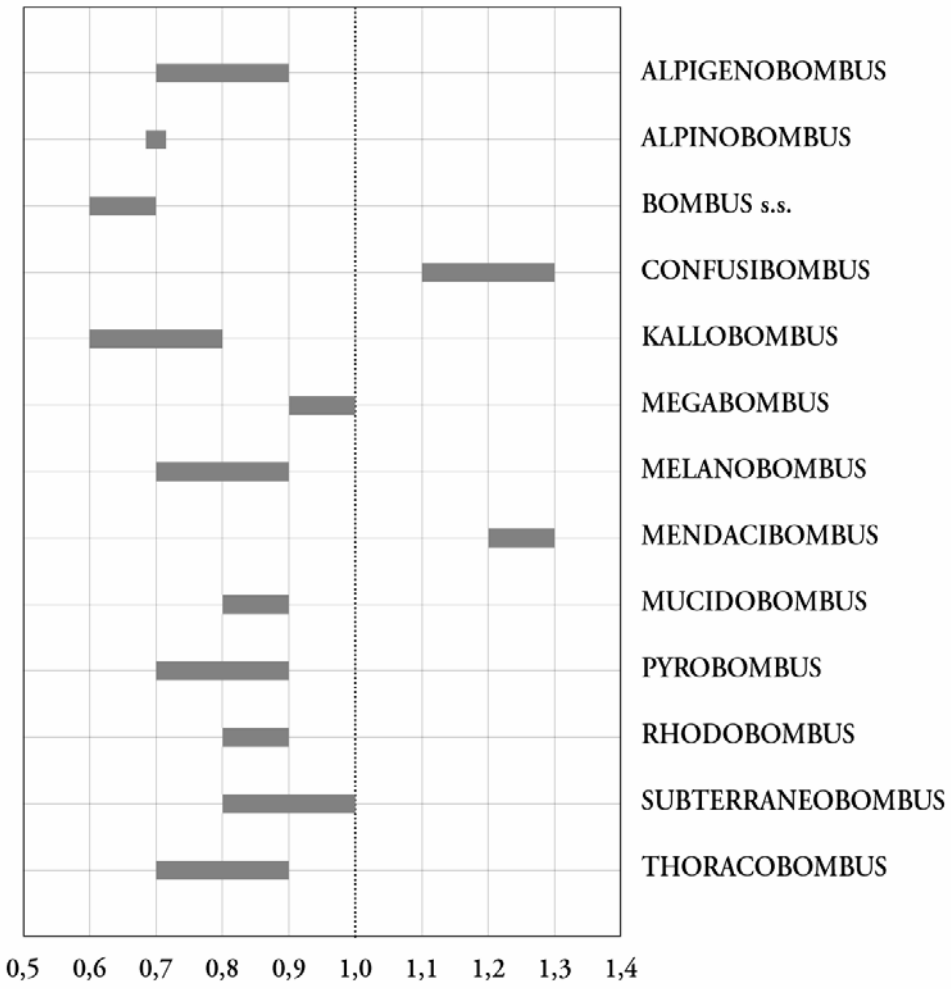
The malar area comprises the lateral surface of the head between the insertion of the mandible and the bottom of the eye. The length/width proportions of this area differ considerably from Author to Author because of the different ways in which the measurements were taken. In a bid to facilitate the measurement of the area, we took the distance between the upper margin of the mandible and the lower extremity of the mandibular condyle as the width, and the lesser distance between the eye and the mandible as the length, taken in correspondence with the central concavity of the articulation (fig. 5). On the basis of this relationship it is possible to distinguish three fundamental types of malar area; broader than long (fig. 4), of equal length and width (fig. 5), and longer than broad (fig. 6). The proportions worked out for the subgenera appear in graph 1A.

ANTENNAE

The measurements and proportions of the antennal segments III, IV and V are of useful diagnostic value; more exactly, we appraised antennal segment III's length in proportion to its distal width, and its length to the sum of the length of segments IV and V. And in this instance, too, problems arise over taking measurements, as some of the segments are cut on the slant. So we looked at the antenna from above and in profile, taking the measurements both from the two sides and from the centre of the segments: the data given are the average of these measurements. The width of antennal segment III was measured at the level of the articulation between III and IV.



Graph 1 – Comparison of the length/width proportions of antennal segment III and length/breadth of the malar area



Graph 2 – Relationship between the length of antennal segment III
and the overall length of antennal segment IV and V

The length/width proportion of antennal segment III appears in graph 1; for example, in fig. 7a, the length is more than twice the width and in fig. 7b is less than twice the width.

The relationship between the length of segment III and the overall length of segments IV and V is of no great diagnostic value, though it does enable *Mendacibombus* and *Confusibombus* to be clearly distinguished from the other subgenera (graph 2, fig. 7c).

The data relative to length/width proportions of antennal segment III have been compared with length/width of the malar area and with length of the malar area/length of antennal segment III proportions (graph 1A, B). The distribution of the subgenera thus obtained, natural variability being taken into account, proved to be of great value in establishing their separation; indeed, an appraisal of these proportions is in itself sufficient to identify various subgenera.

MANDIBLES

The structure, the protuberances and the hollows of the surface of these appendices, which play an important role in characterising the different groups of Apoidea (MICHENER & FRASER, 1978), are of great help in the discrimination of the subgenera in question.

Fig. 8 shows all the details of the outline of the part, the furrows and the keels of its surface. Table 1 lists the various descriptive elements of the mandible, as they have been verified in the different subgenera.

In particular, regarding the basal keel, whose presence allows the differentiation between section Odontobombus (fig. 9) and section Anodontobombus, in which it is absent (fig. 10), it is more clearly seen if the mandible is viewed from the angle of the articulation, and in a more or less diagonal light.

The incisura lateralis is “evident” when it shows distinct margins and is about as deep as the edge of the anterior margin of the mandible, or at least half as deep, (fig. 11a, 11b), while it is taken as “absent” or “not considerable” when it is either not there at all or is only faintly discernible, with ill-defined margins and does not reach the middle of the anterior edge of the mandible (fig. 11c).

The sulcus obliquus may be evident. In such cases its course is always distinct and regular, marked – and as a rule plenty – with hairs. The sulcus is, distally, wide and deep. It then narrows gradually so that the two branches of the condylar ridge are clearly separated, the upper one being generally pointed. In its more characteristic form, the sulcus obliquus is the same shape as the accompanying groove (fig. 9). In other cases, the course of the sulcus obliquus may be irregular, short, shallow, sometimes partially obliterated in width or depth by the irregular outline of the ridges; it may be more or less hairless or sparsely covered with hair; the distal part is normally wide and hairy, but the division between the two branches of the condylar ridge is generally confused and the upper branch is usually blunted at the end (fig. 10). The sulcus obliquus is deemed to be “absent” when it is not there at all (fig. 12) or is simply a slight hairless depression (fig. 13).

CHARACTERISTICS OF LITTLE DIAGNOSTIC VALUE

In practice, these are all those characteristics which, being described subjectively, have been difficult to check directly and to make comparisons with indications given by different Authors. With such parameters it has not been possible to define all the subgenera in objective terms and with total conviction. But some of them, now and then, have proved valid for the identification of certain subgenera.

Dorsal furrow of the genae. A slight depression running along the dorsal margin of the compound eye, crossing the top of the *gena*, which can be more or less evident (fig. 3) or not present at all; it is not always possible to define its presence with any certainty.

Forehead. The aspects taken into consideration concern the type of sculpture and the extension of the non-punctured areas, the description of which is always strongly influenced by subjective observation and appraisal.

Ocelli. Their disposition along a line more or less straight and the distance between the eye and the lateral ocellus, measured in ocellar diameters, do not prove to be of any general value. Disposition in relation to the supraorbital line is characteristic only of the *Kallobombus* queens (fig. 17); such characteristic, together with the sculpture of the oculo-ocellar field, has been used in the keys to distinguish this subgenera from *Pyrobombus* (fig. 18).

Clypeus. The aspects of this part of the head that are taken into consideration are the proportions, the convexity, the puncturing and the apical impressions (fig. 19). The variability of the length/width relationship of the clypeus within single subgenera is such as not to permit their individualisation; furthermore, the taking of measurements is sometimes complicated by the presence of hairs that obscure the superior margin of the clypeus. So this parameter has not been taken into consideration here.

Evaluation of the other elements, which, however, always calls for a subjective analysis, does not enable one to separate the different subgenera, but may sometimes be used in direct comparison between groups or single species.

Labrum. Study of the labrum comprises an examination of the shape of the tubercles and measurement of the dimensions of the furrow and the lamella (fig. 20, 21). Description of the tubercles is generally treated subjectively by the observer which means that it is not possible to define these characteristics with any degree of precision; furthermore, particular conformations of the lamella and the furrow can render their measurement equally uncertain.

There is one characteristic structure, and therefore of diagnostic value, present in *Bombus s.s.* (fig. 22): this is the noticeable depression of the tubercles and the conformation of the furrow which make the labrum look like three contiguous dimples.

CONCLUSIONS

The revision of the female head morphology of the gen *Bombus s.l.* allows a clear definition of certain essential characteristics and a precise indication of terms of measurement. As a result it has been possible to draw up a simplified dichotomic key comprising the 13 subgenera to which the species found in Italy belong. It is given below and, as a check, may be integrated with the descriptive characteristics of the other parts of the body.

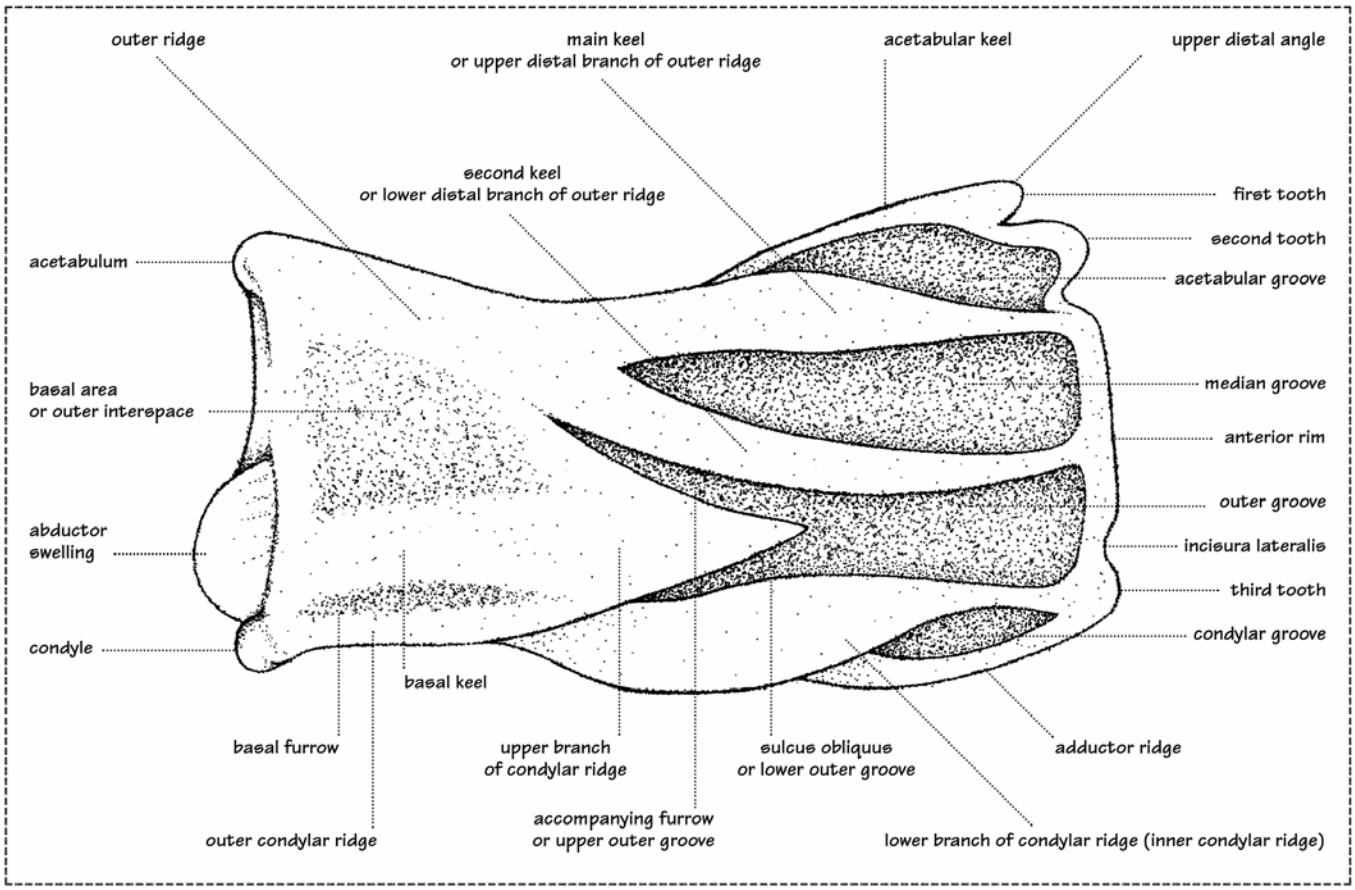


Fig. 8

Table 1 – Diagnostic characters of the mandibles.

1. MANDIBLES WITH 2-3 TEETH; MAIN KEEL CONFLUENT IN THE ANTERIOR MARGIN

a) basal keel absent:	sulcus obliquus absent	sulcus obliquus present, more or less distinct
incisura lateralis absent or not considerable	(*Kallobombus*)	*Melanobombus*
incisura lateralis evident	(*Kallobombus*), (*Pyrobombus*)	*Alpinobombus*, *Bombus s.s.*, (*Pyrobombus*)
b) basal keel present:	sulcus obliquus absent	sulcus obliquus present, more or less distinct
incisura lateralis absent or not considerable	–	(*Megabombus*), *Rhodobombus*, *Thoracobombus*
incisura lateralis evident	–	(*Megabombus*), *Mucidobombus*, *Subterraneobombus*

2. MANDIBLES WITH 2-3 TEETH; MAIN KEEL INTERRUPTED BEFORE ANTERIOR MARGIN

main keel ending near the anterior margin (fig. 14)	*Mendacibombus*
main keel ending clearly far from the anterior margin (fig.15)	*Confusibombus*

3. MANDIBLES WITH 5-6 TEETH (fig.16) *Alpigenobombus*

SIMPLIFIED DICHOTOMIC KEY FOR THE IDENTIFICATION
OF THE SUBGENERA OF THE GENUS *BOMBUS s.l.*

QUEENS AND WORKERS

1. Mandible with 5-6 teeth (fig. 16). Malar area about half as long as its distal width and shorter than antennal segment III ***Alpigenobombus***

– Mandible with 2 teeth in the upper distal corner; the presence of the incisura lateralis may form a third tooth at the bottom. Malar area longer **2**

2. Mandible without basal keel (fig. 10). Longitudinal axis of the eye towards the abductor swelling of the mandible (Anodontobombus) (fig. 3) **3**

– Mandible with basal keel (fig. 9). Longitudinal axis of the eye towards the mandibular condyle or below it (Odontobombus) (fig. 2) **9**

3. The main keel of the mandible is truncated and does not reach the anterior edge, ending before it. Antennal segment III longer than antennal segments IV and V together (fig. 7c) **4**

– The main keel of the mandible reaches the anterior edge. Antennal segment III shorter than IV and V together **5**

4. The main keel ends just before the anterior edge (fig. 14). Malar area longer than its distal width ***Mendacibombus***

– The main keel ends at a clear distance from the anterior edge (fig. 15). Malar area never longer than broad ***Confusibombus***

5. The length of the malar area is equal to its distal breadth and greater than 1.5 times the length of antennal segment III ***Alpinobombus***

– The length of the malar area is less than its distal breadth and definitely less than 1.5 times the length of antennal segment III **6**

6. Mandible with incisura lateralis either absent or indistinct (fig. 11c) and sulcus obliquus present. The length of antennal segment III is equal to or greater than twice its distal width ***Melanobombus***

[*Kallobombus* may have the mandible without incisura lateralis, but the sulcus obliquus is absent (fig. 12) and the length of antennal segment III is less than twice its distal breadth. See no. 8]

– Mandibola with incisura lateralis evident (fig. 11a) and sulcus obliquus absent or more or less evident. The length of antennal segment III is less than or equal to twice its distal breadth **7**

7. Mandible with sulcus obliquus always evident (fig. 9) and covered to a greater or lesser degree with short thick hairs, distally wide and deep so that the two branches of the condylar ridge are well separated. The labrum is characteristic with three contiguous dimples resulting from the deep concave depression of the tubercles (fig. 22) ***Bombus s.s.***

– Mandible with sulcus obliquus absent or replaced by a short and slight hairless depression (fig. 13), or else with shallow sulcus, irregular in direction and more or less sparsely covered with hairs; the separation between the two branches of the condylar ridge is usually confused. The labrum is never as that described above **8**

8. The sulcus obliquus is always clearly absent (fig. 12). Ocelli lying above the supraorbital line or crossed by it. Among the coarse puncturing in the oculo-ocellar space, along the inner margin of the eyes, there is a band of finer punctures about half as wide as the space between the compound eye and the lateral ocellus (fig. 17) ***Kallobombus***

– Sulcus obliquus ranging from indistinct to more or less evident. Ocelli lying below the supraorbital line (in the workers the ocelli are above this line). Among the coarse puncturing in the oculo-ocellar space, along the inner margin of the eyes, the band of finer punctures is very narrow, sparse or non-existent (fig. 18) ***Pyrobombus***

9. Mandible with incisura lateralis evident, about half as deep as the anterior edge of the mandible (fig. 11b). Malar area equal to or slightly longer than its distal width **10**

[*Megabombus* may have the incisura lateralis distinct, but its malar area is clearly longer than its distal breadth.See no. 12]

– Mandible with incisura lateralis indistinct or non-existent (fig. 11c). Malar area variable in length **11**

10. Labrum with protruding tubercles, distally depressed, the inner edge clearly marked by a contour reaching as far as the lamella; it thus forms a well-defined central ditch, as deep and as wide as a tubercle (fig. 20) ***Subterraneobombus***

– Labrum with tubercles never as described above and somewhat blunted towards the inside; lamella with a thin edge; the central ditch is ill defined, narrower and shallower (fig. 21) ***Mucidobombus***

11. The length of the malar area is slightly less or slightly more than its distal width and is 1.2-1.6 times the length of antennal segment III ***Thoracobombus***

– The length of the malar area is 1.1-1.5 times its distal width, and 1.7-1.9 times the length of antennal segment III **12**

12. The lower edge of the II tooth of the mandible reaches, or almost, the upper margin of the main keel (fig. 23). Length of antennal segment III 2.1-2.8 times its distal width ***Megabombus***

– The lower edge of the II tooth of the mandible is distinctly separated from the upper margin of the main keel and ends at the middle of the acetabular groove (fig. 24). Length of antennal segment III 1.8-2.1 times its distal width ***Rhodobombus***

REFERENCES

ALFORD D. V., 1975 – *Bumblebees*. - Davis-Pointer, London.

ELFVING R., 1960 – *Die Hummeln und Schmarotzerhummeln Finnlands*. - Fauna fenn., 10: 1-43.

FAESTER K., HAMMER K., 1970 – *Systematik der Mittel- und Nordeuropäischen* Bombus *und* Psithyrus. - Ent. Meddr, 38: 257-302.

FRANKLIN H. J., 1912 – *The Bombidae of the New Word.* - Trans. Am. ent. Soc., XXXVIII: 177-486.

FRANKLIN H. J., 1913 – *The Bombidae of the New Word.* - Trans. Am. ent. Soc., XXXIX: 73-200.

HAMMER K., HOLM N. SV., 1970 – *Nøgle til bestemmelse af danske humlebier og snyltehumler.* - Natur Mus., Århus, 14 (2-3): 1-22.

HEDICKE H., 1930 – *Hautflüger* (*Hymenoptera)*. In: BROHMER P., EHRMANN P., ULMER G. *Die Tierwelt Mitteleuropas.* - Verlag Von Quelle & Meyer, Leipzig. (V. Band, Lief. 1, Insekten 2. Teil: 230-244).

INTOPPA F., PIAZZA M.G., RICCIARDELLI D'ALBORE G.C., 1995 – *Catalogo bibliografico delle specie di Bombidae (Hymenoptera Apoidea) segnalate per l'Italia.* - Apicoltura, 10, suppl.: 1-135.

KNECHTEL W. K., 1955 – Hymenoptera. Subfamilia Apinae. - Fauna Repub. pop. rom. Insecta, IX (1): 1-113.

KRÜGER E., 1920 – *Beiträge zur Systematik und Morphologie der mittel-europäischen Hummeln.* - Zool. Jb., Abt. Syst., 42: 289-464.

KRÜGER E., 1924 – *Analytische Studien zur Morphologie der Hummeln. I. Die Indices des Kopfes der Hummelweibchen.* - Zool. Jb., Abt. Syst., 48: 1-128.

KRUSEMAN G., 1945 – *Tabellen tot het bepalen van de Nederlandsche soorten der Genera* Bombus *Latr. en* Psithyrus *Lep*. - Tijdschr. Ent., LXXXIII: 173-188.

LABOUGLE J. M., 1990 – Bombus *of Mexico and Central America.* - Univ. Kans. Sci. Bull., 54 (3): 35-73.

LØKEN A., 1973 – *Studies on Scandinavian Bumble Bees*. - Norsk ent. Tidsskr., 20: 1-218.

MAUSS V., 1988 – *Hinweise zum Bestimmungsschlüssel.* In: HAGEN E. VON. *Hummeln: bestimmen, ansiedeln, vermehren, schutzen.* - Melsungen, Verlag J. Neudamm.

MICHENER C. D., 1944 – *Comparative external morphology, phylogeny, and a classification of the bees.* - Bull. Am. Mus. nat. Hist., 82 (6): 157-326.

MICHENER C. D., 1990 – *Classification of the Apidae.* - Univ. Kans. Sci. Bull., 54 (4): 75-164.

MICHENER C. D., FRASER A., 1978 – *A Comparative Anatomical Study of Mandibular Structure in Bees.* - Univ. Kans. Sci. Bull., 51 (4): 463-482.

MILLIRON H. E., 1971 – *A monograph of the western hemisphere bumblebees. I. The genera* Bombus *and* Megabombus *subgenus* Bombias. - Mem. ent. Soc. Can., 82: 1-80.

MOURE J. S., SAKAGAMI S. F., 1962 – *As Mamangabas Sociais do Brasil.* - Studia Ent., 5 (1/4): 65-194.

PITTIONI B., 1937 – *Die Hummelfauna des Kalsbachtales in Ost-Tirol.* - Festschr. 60. Geb. E. Strand, III: 64-122.

PITTIONI B., 1938 – *Die Hummeln und Schmarotzerhummeln der Balkan-Halbinsel I. Allgemeiner Teil.* - Mitt. K. naturw. Inst. Sofia, XI: 12-69.

PITTIONI B., 1939 – *Die Hummeln und Schmarotzerhummeln der Balkan-Halbinsel II. Spezieller Teil.* - Mitt. K. naturw. Inst. Sofia, XII: 49-114.

PRYS-JONES O. E., CORBET S. A., 1987 – *Bumblebees*. - Cambridge University Press, Cambridge.

QUILIS PEREZ M., 1927 – *Los Apidos de España: Género* Bombus *Latr.* - An. Inst. nac. 2a. Enseñanza Valencia, 1927: 1-121.

RICHARDS O. W., 1927 – *The specific characters of the British Humblebees*. - Trans. R. ent. Soc. Lond., 75: 233-268.

RICHARDS O. W., 1968 – *The subgeneric divisions of the genus* Bombus *Latreille*. - Bull. Br. Mus. nat. Hist. (Ent.), 22 (5): 209-276.

STEPHEN W. P., BOHART G. E., TORCHIO P. F., 1969 – *The Biology and External Morphology of Bees.* - Agric. Exp. Stn, Oregon St. Univ., Corvallis.

WILLIAMS P. H., 1991 – *The bumble bees of the Kashmir Himalaya.* - Bull. Br. Mus. nat. Hist. (Ent.), 60 (1): 1-204.

YARROW I. H. H., 1959 – *The Identification of British Bumblebees*. In: FREE J. B., BUTLER C. G. *Bumblebees.* - Collins, London: 173-184.

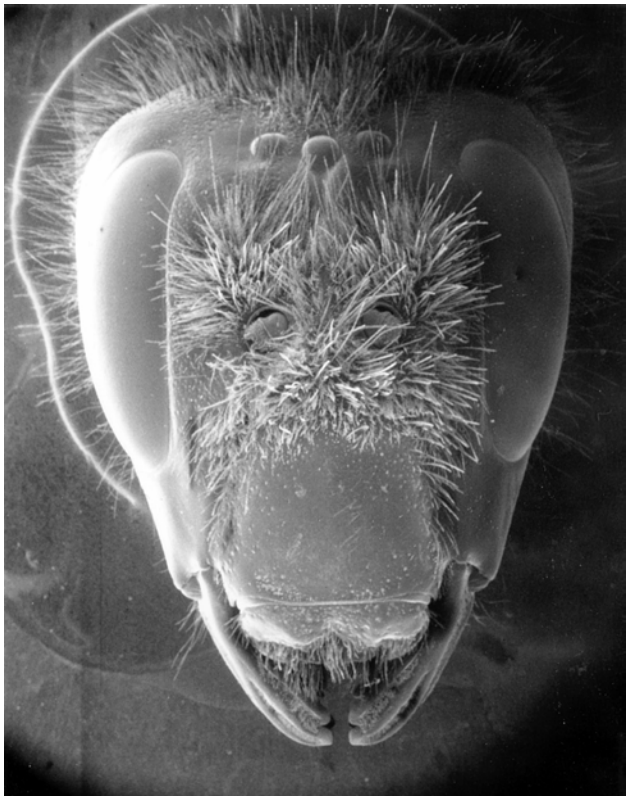
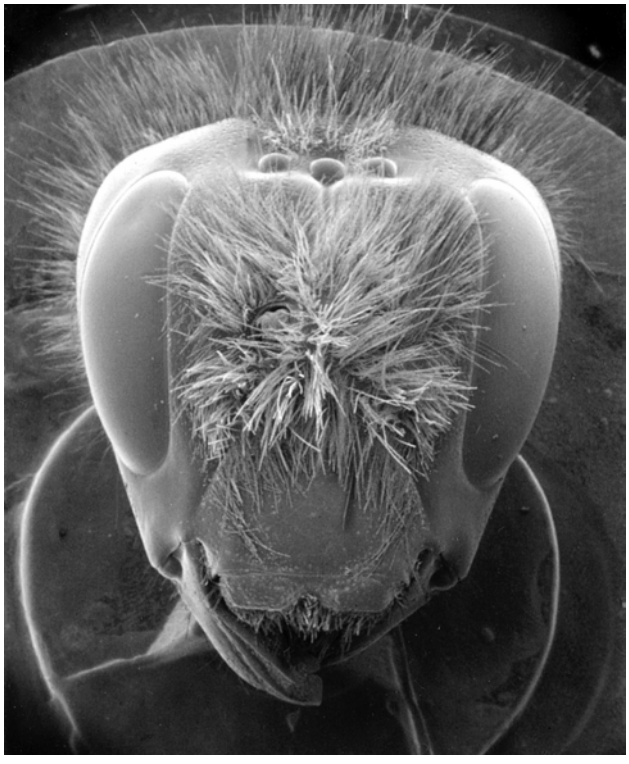


Fig. 1 (a, b)



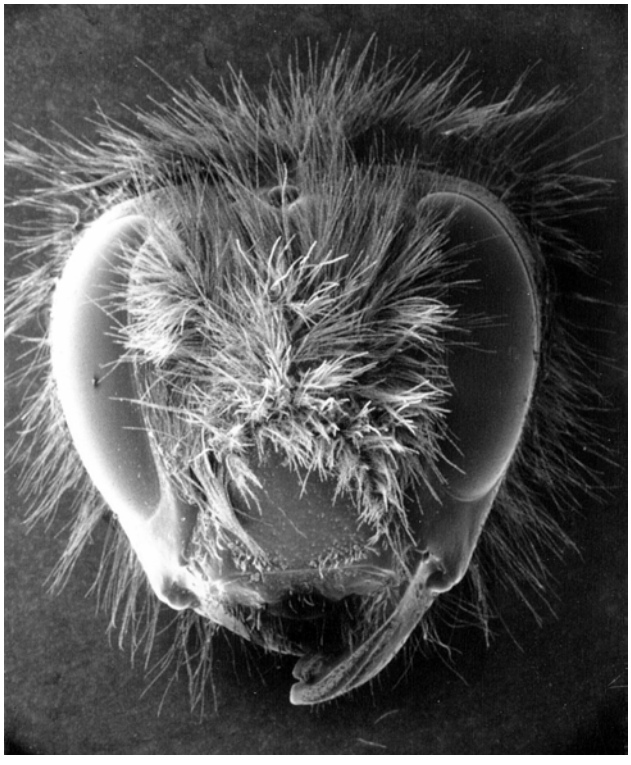


Fig. 1 (c, d)

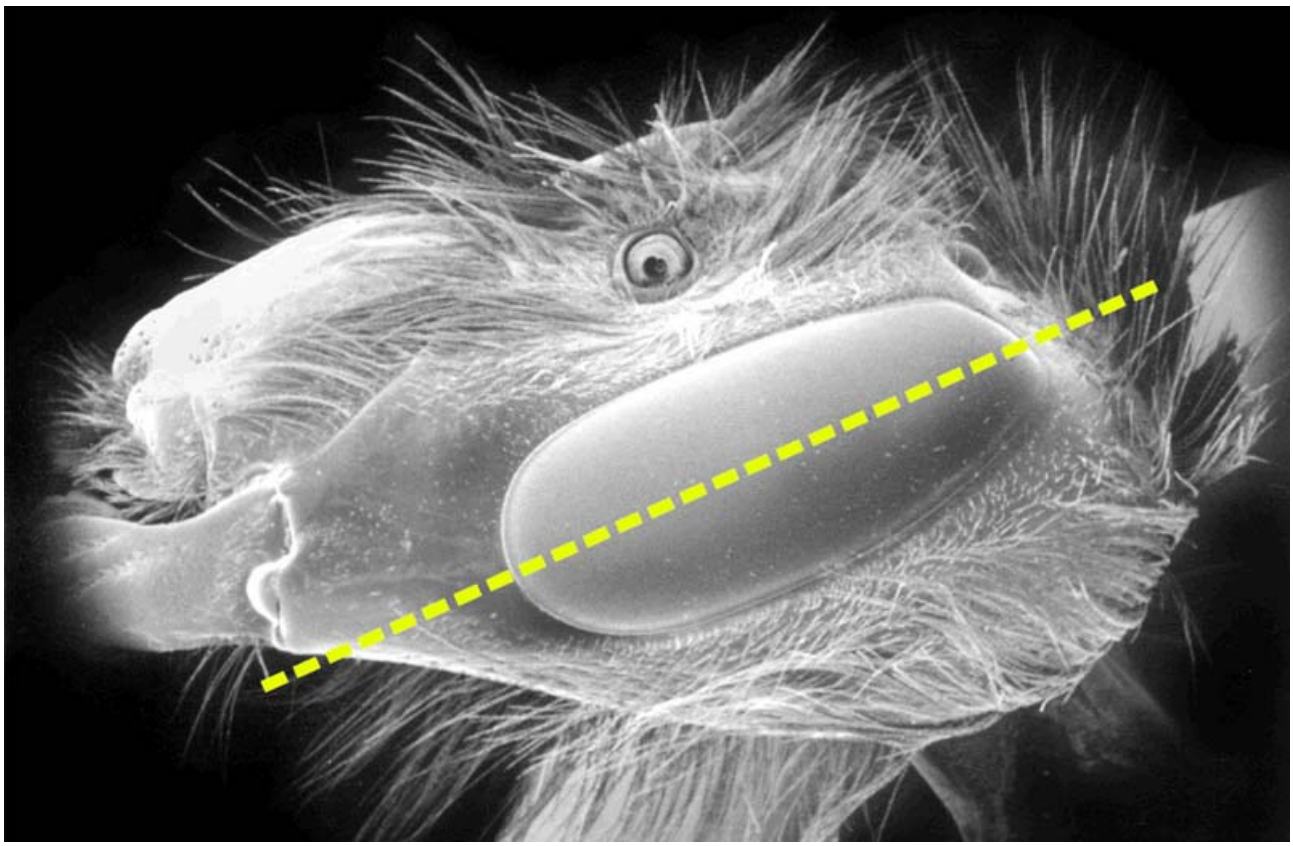


Fig. 2

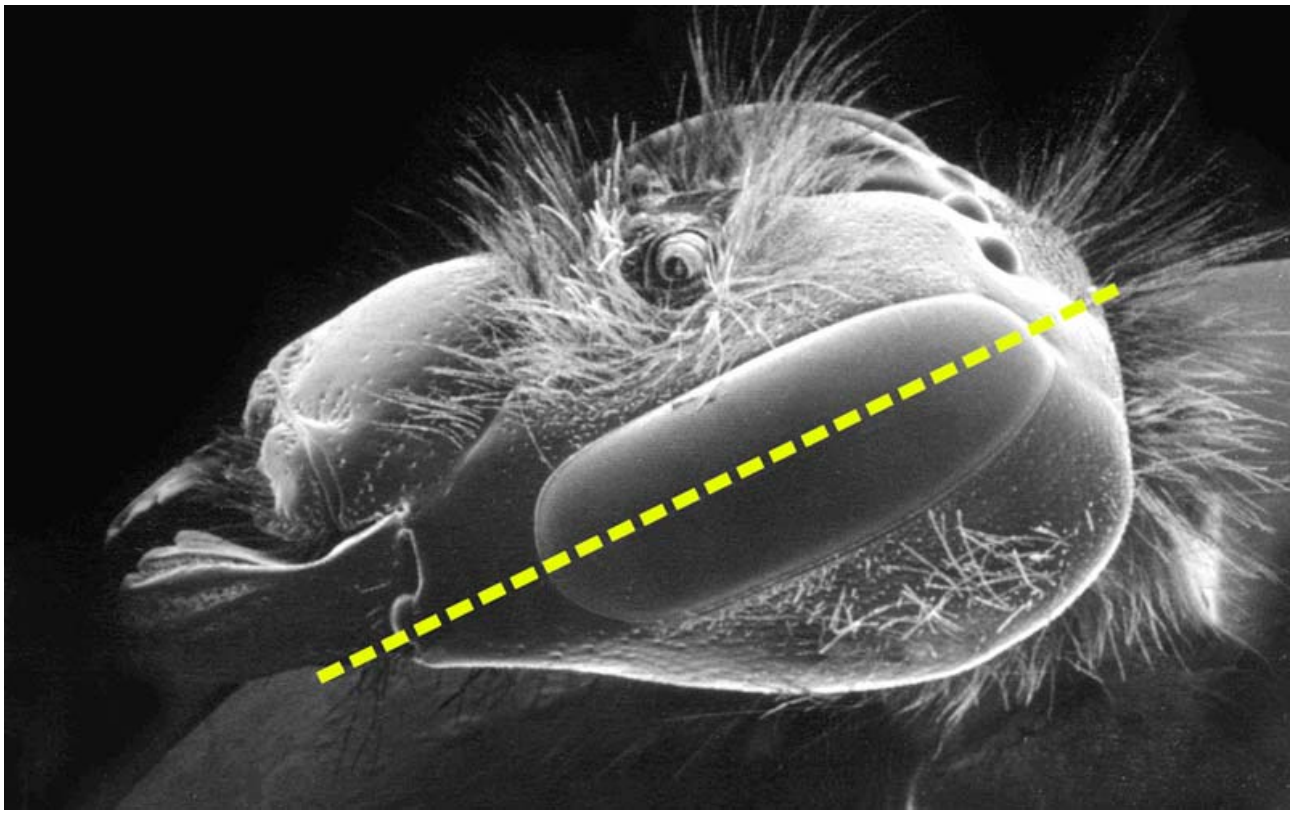


Fig. 3

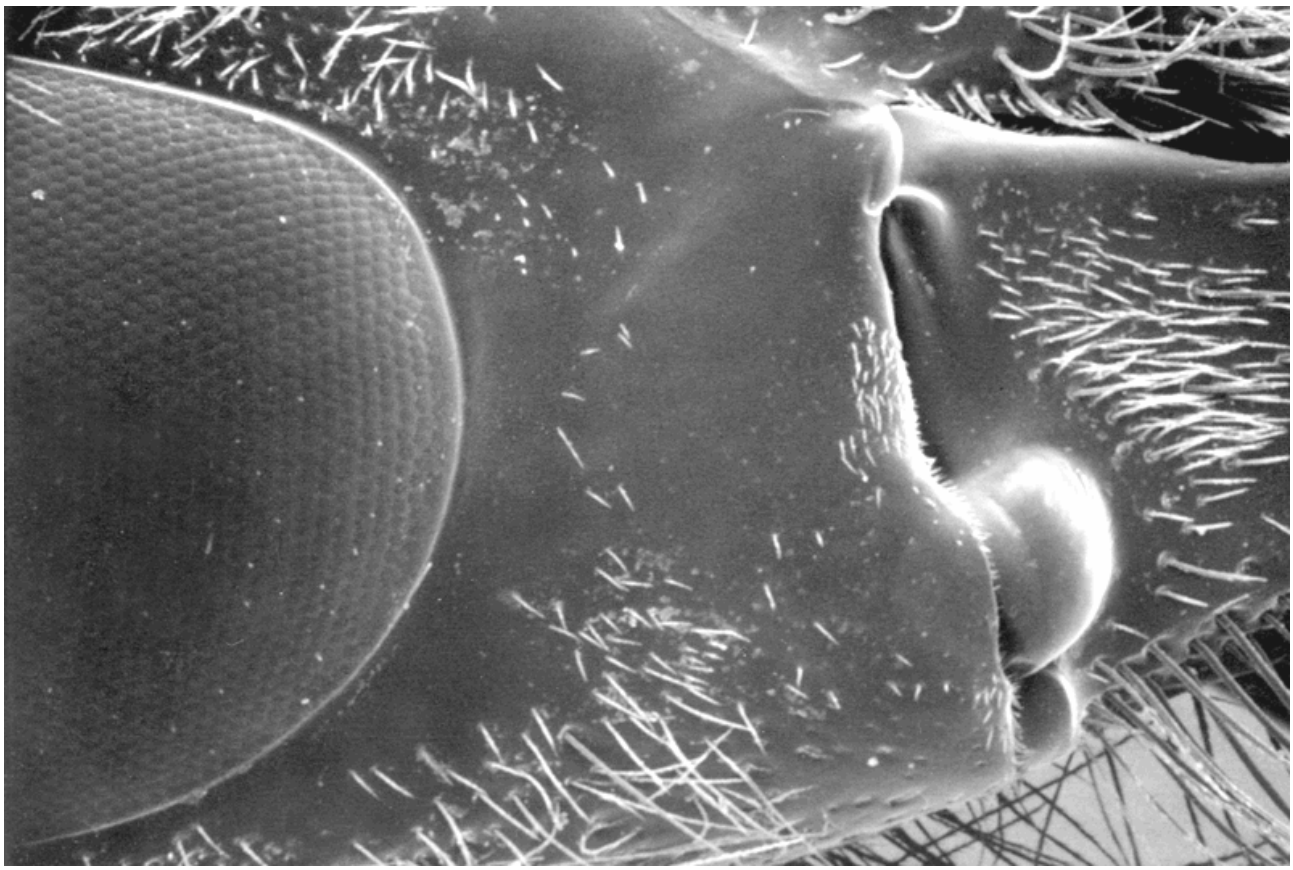


Fig. 4

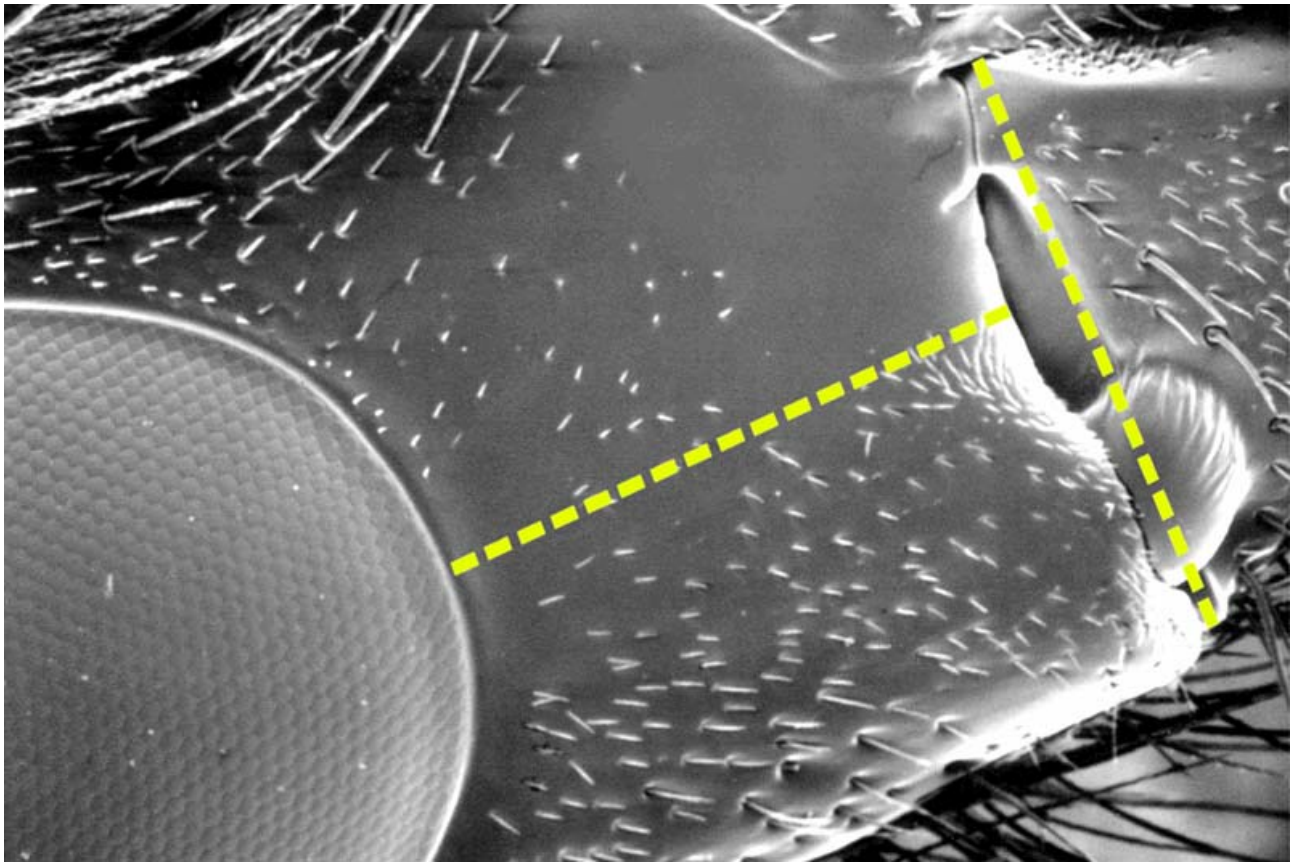


Fig. 5

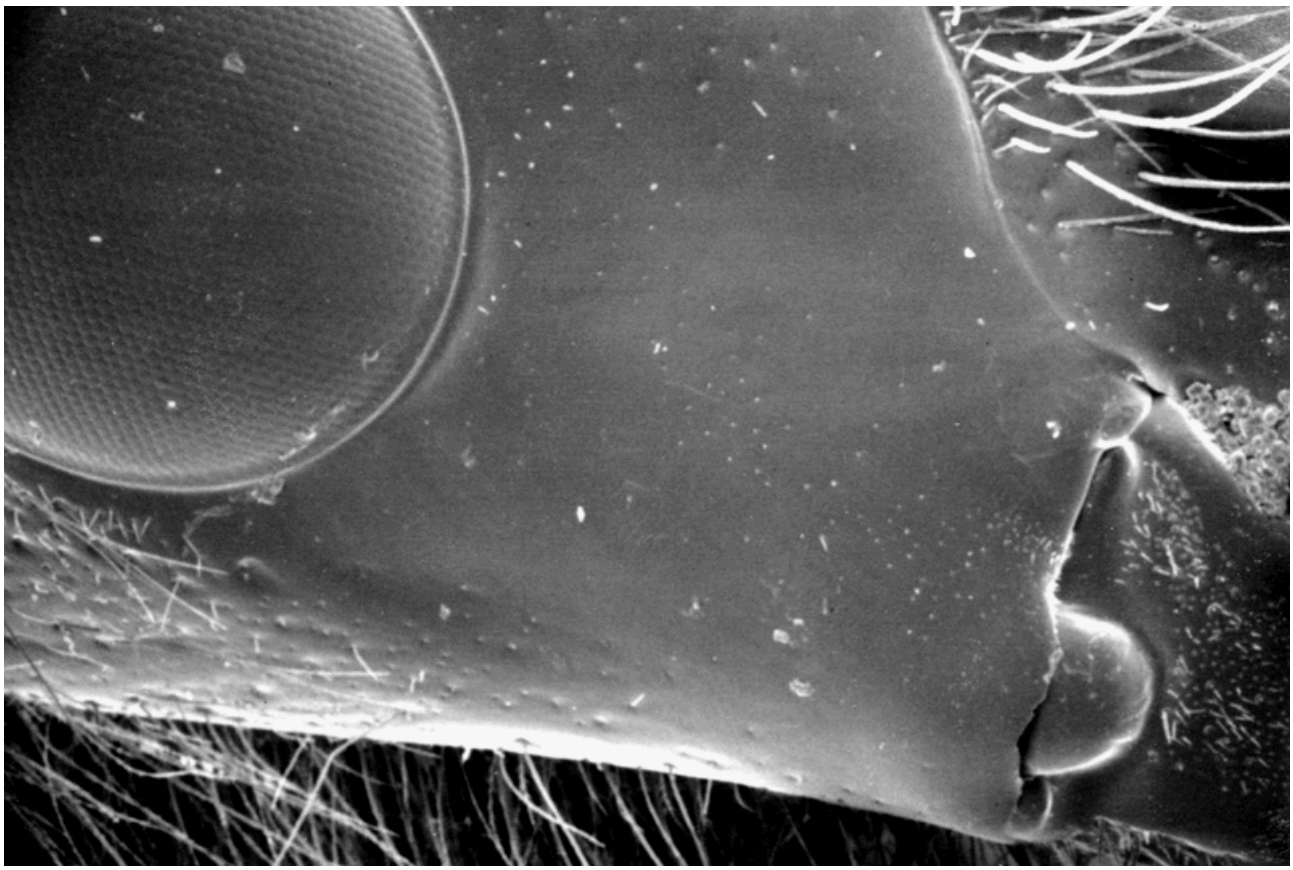


Fig. 6

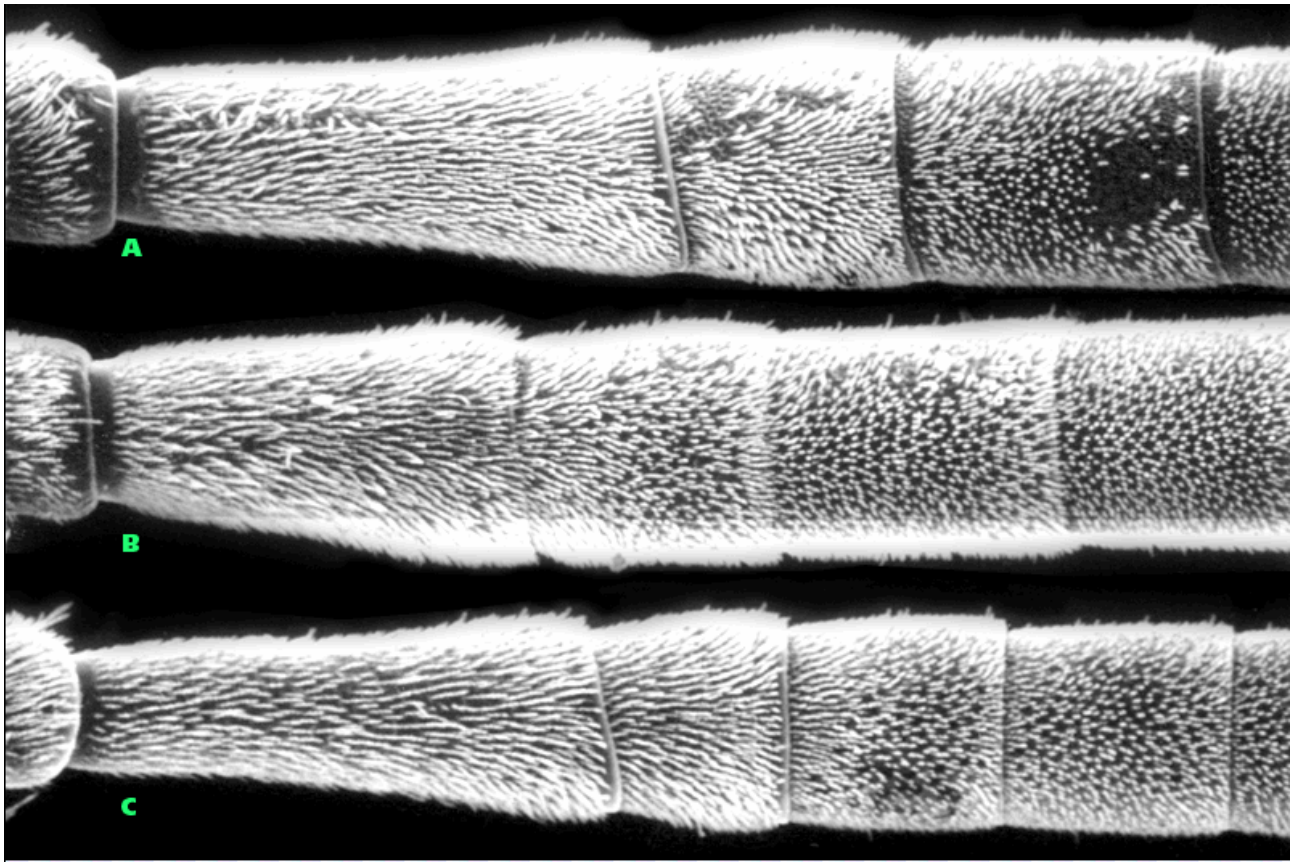


Fig. 7 (a, b, c)

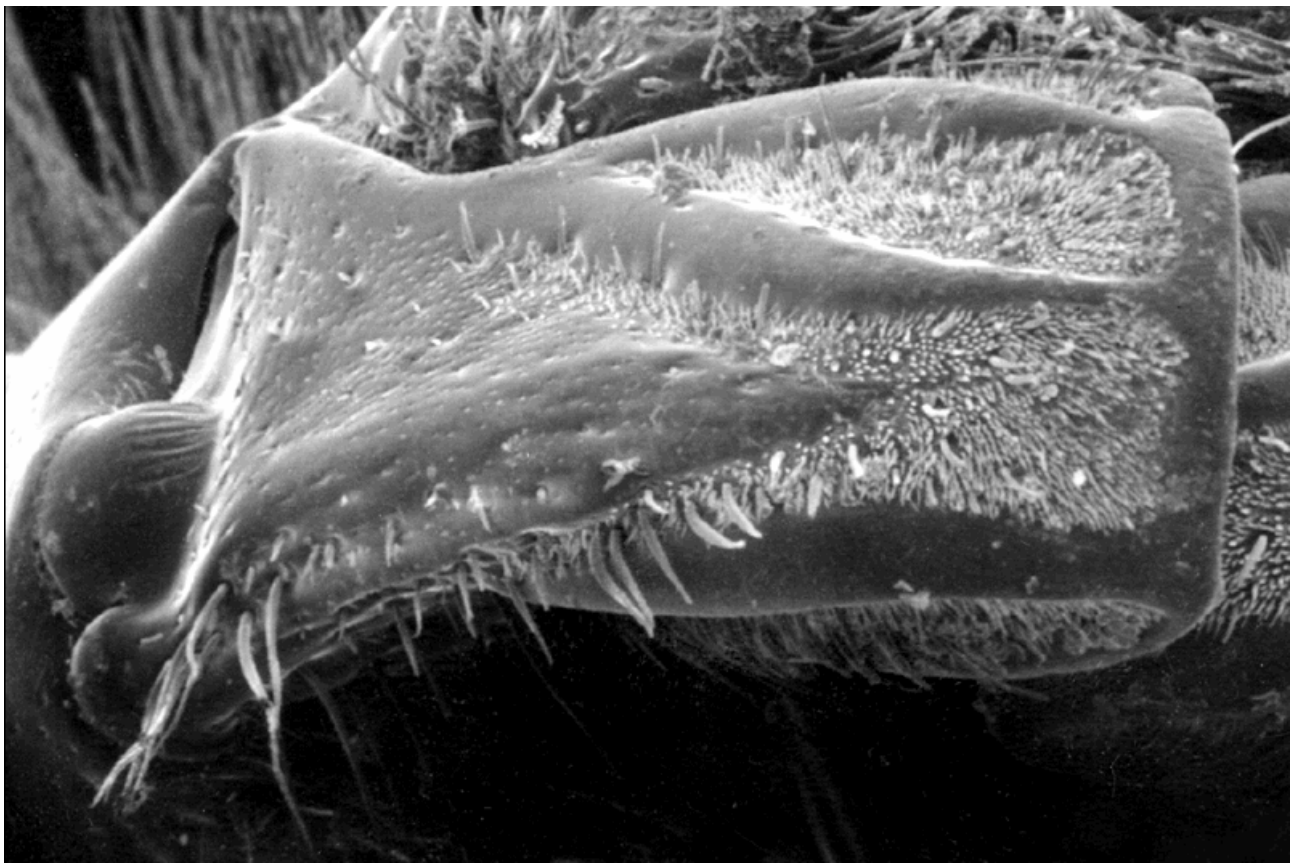


Fig. 9

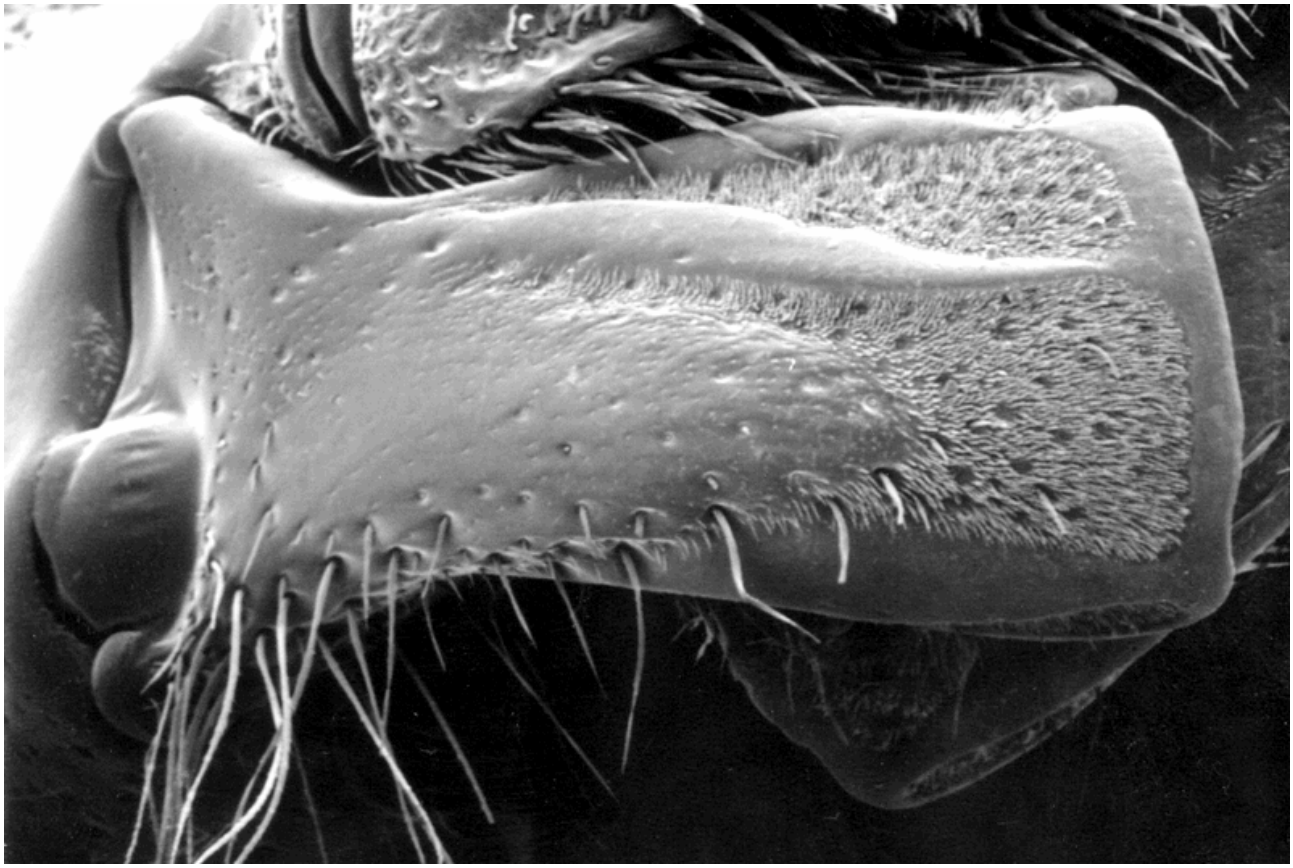


Fig. 10

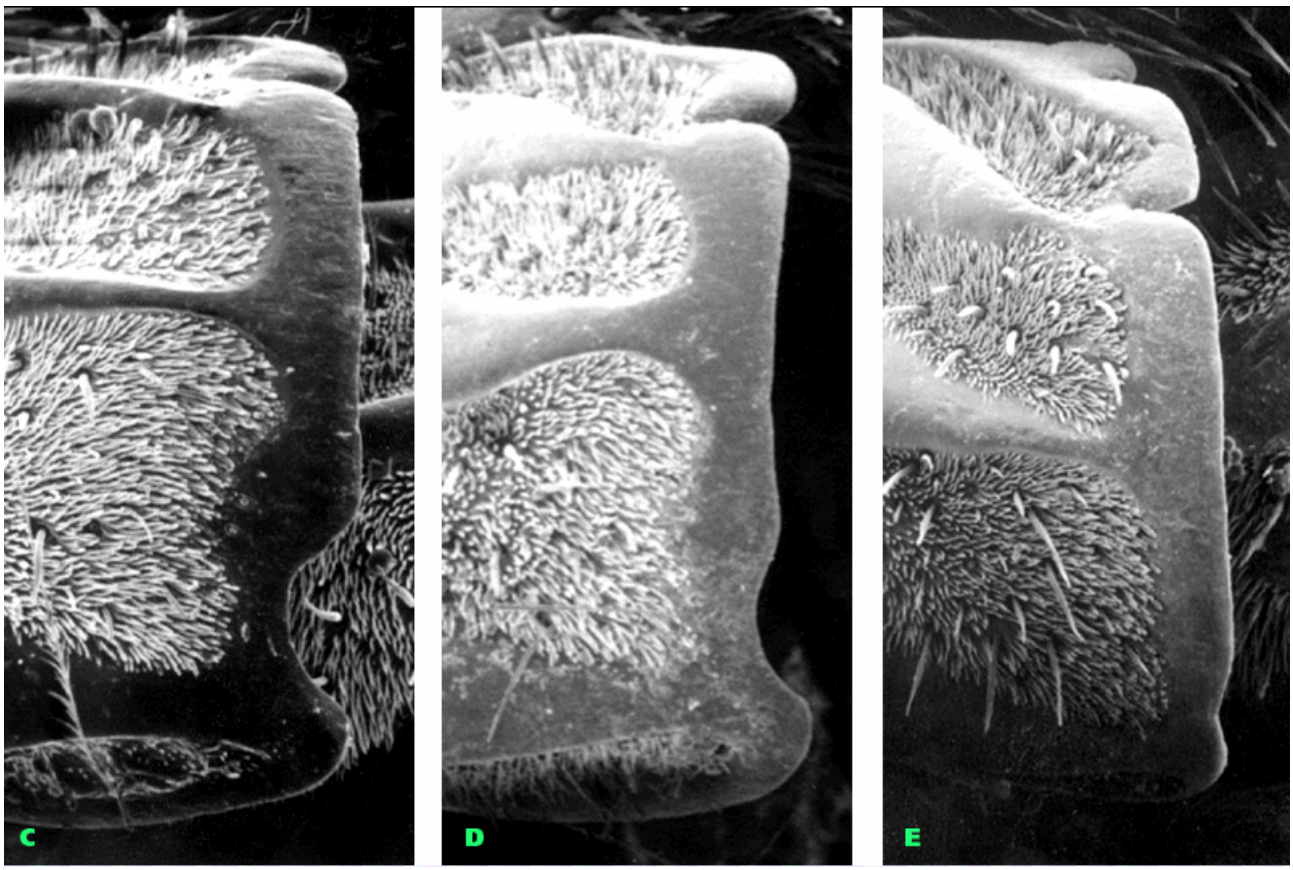


Fig. 11 (a, b, c)

Fig. 12

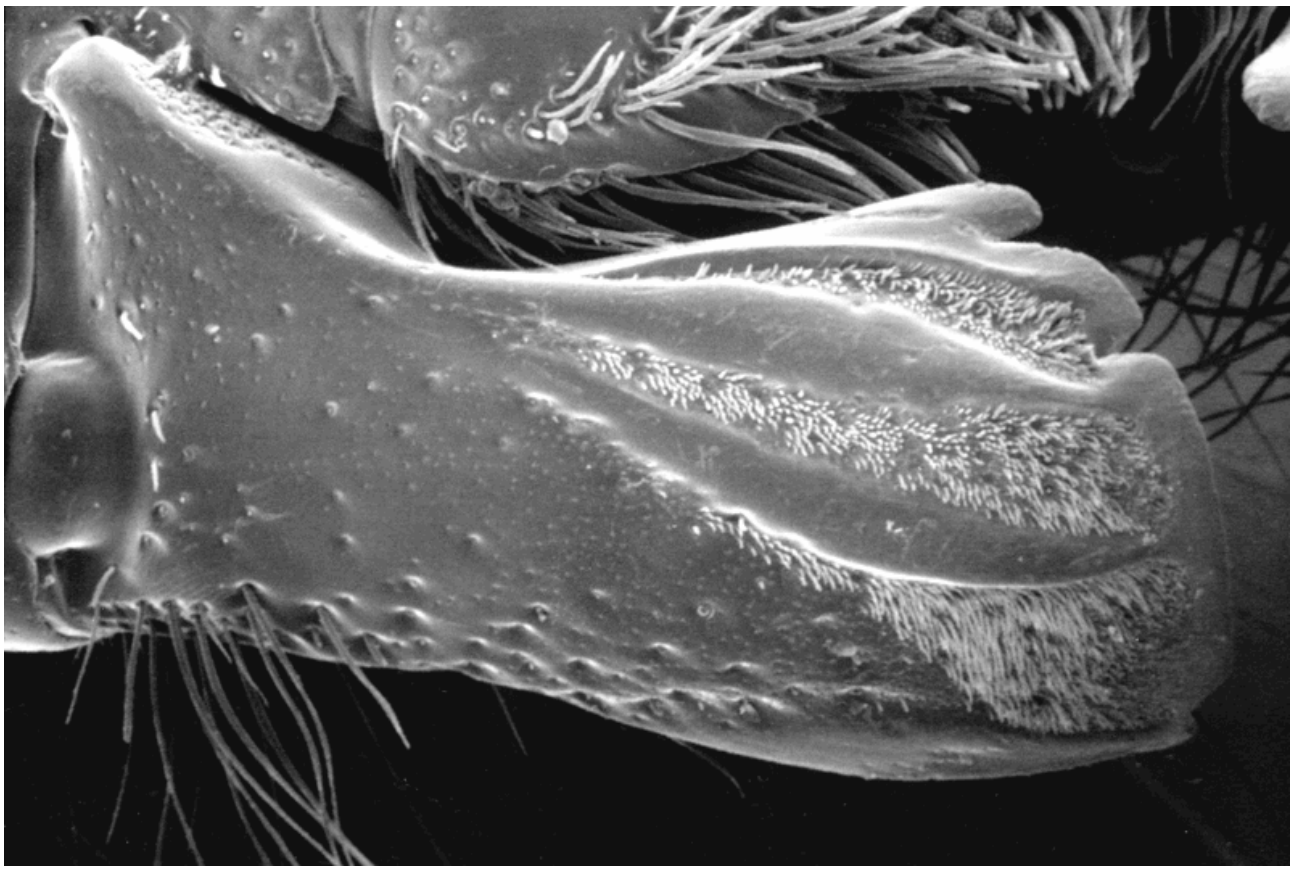


Fig. 13

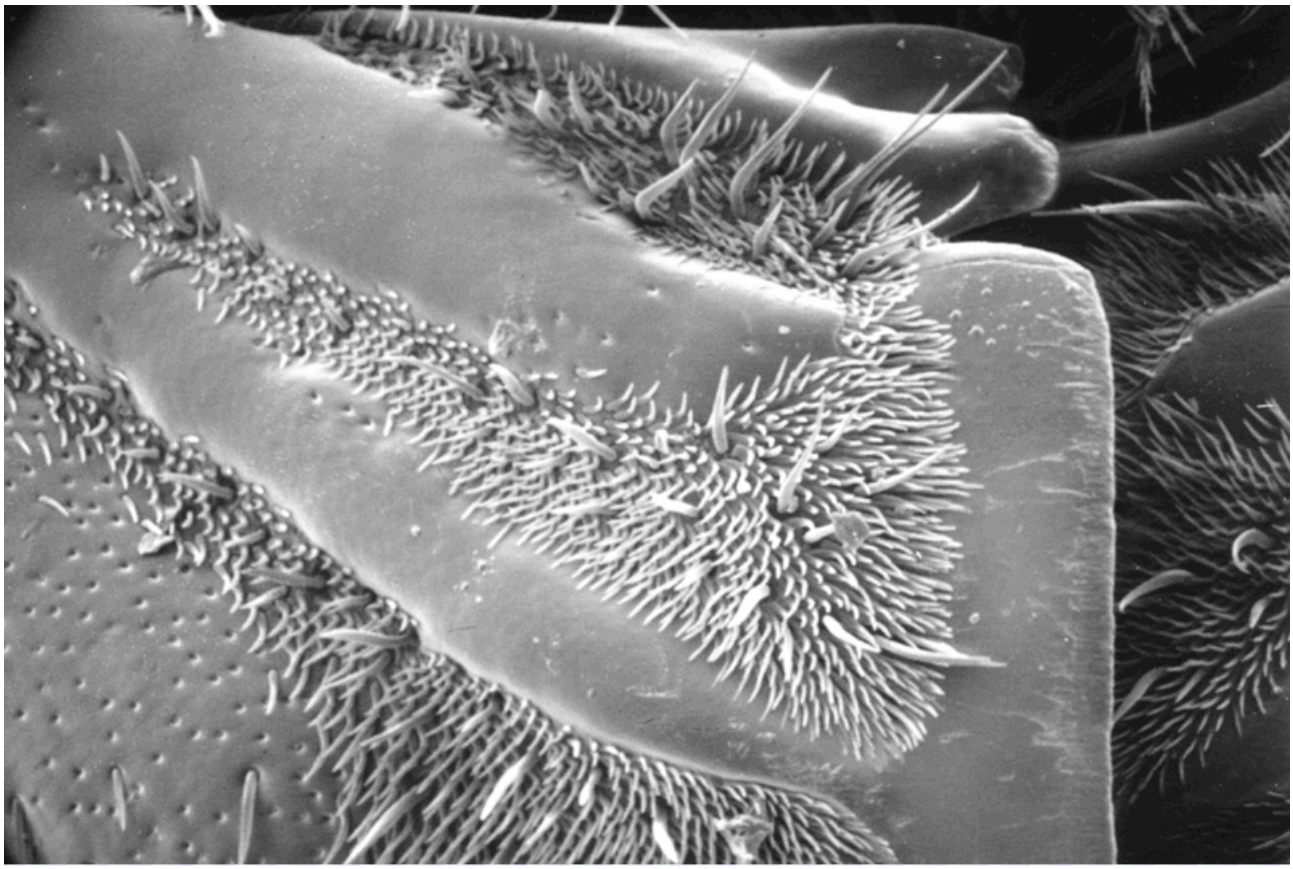


Fig. 14

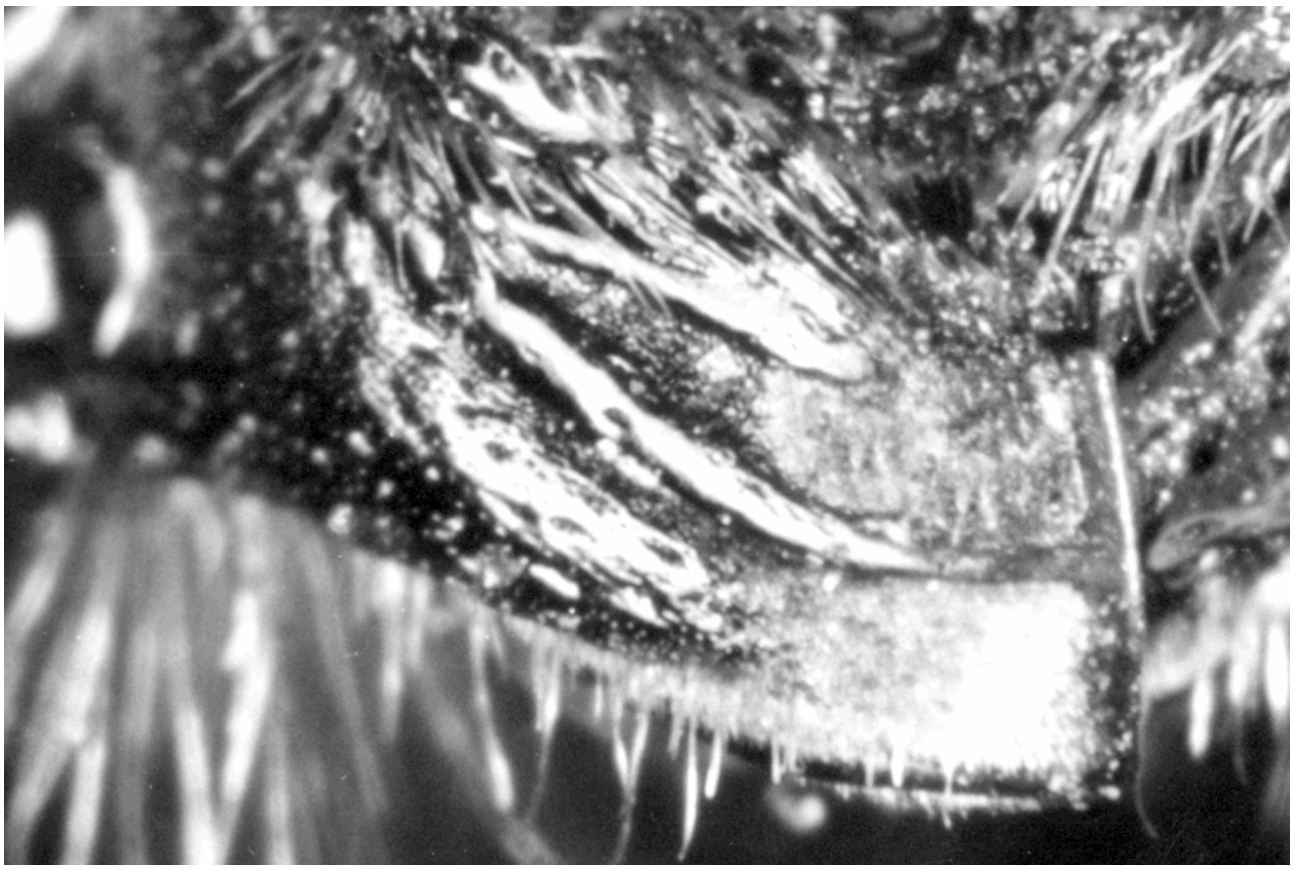


Fig. 15

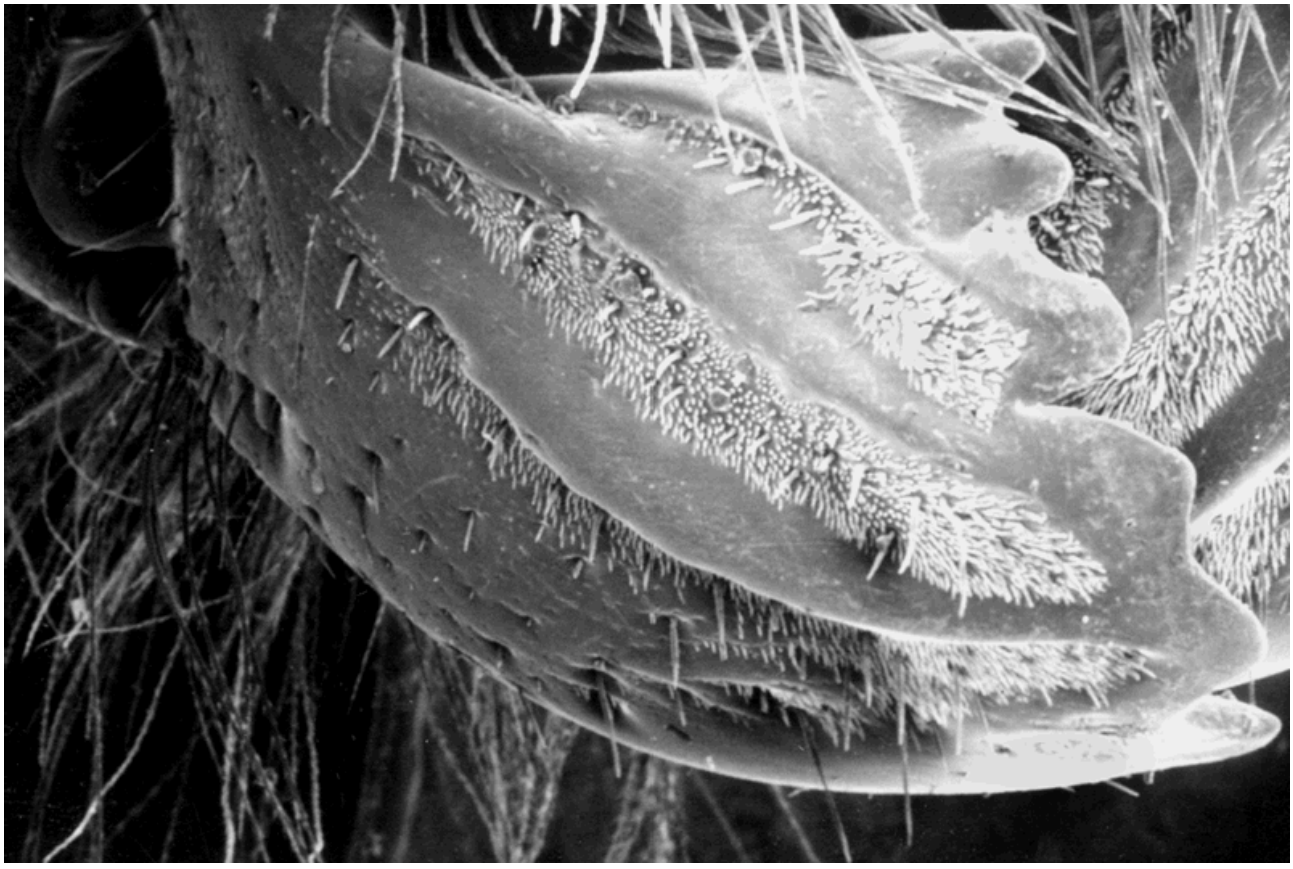


Fig. 16

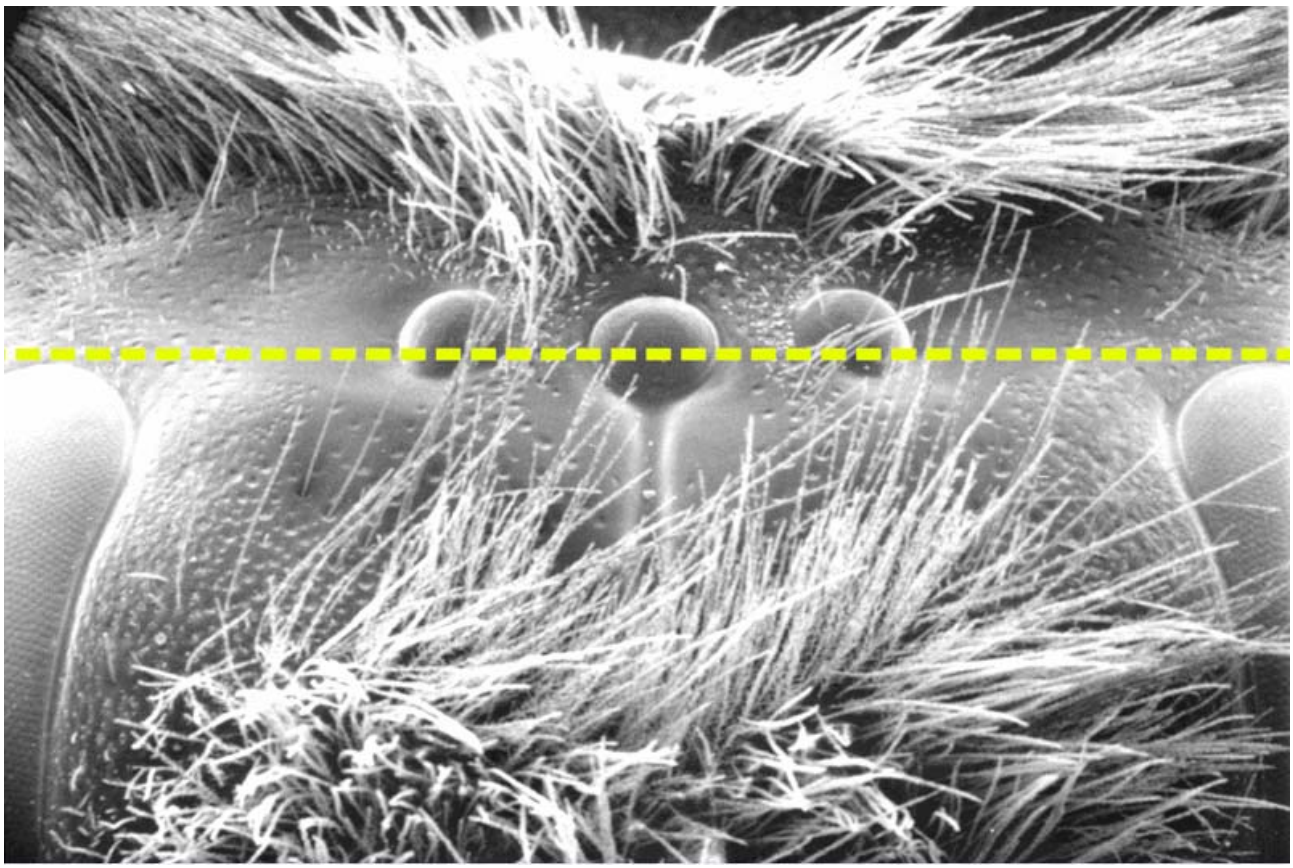


Fig. 17

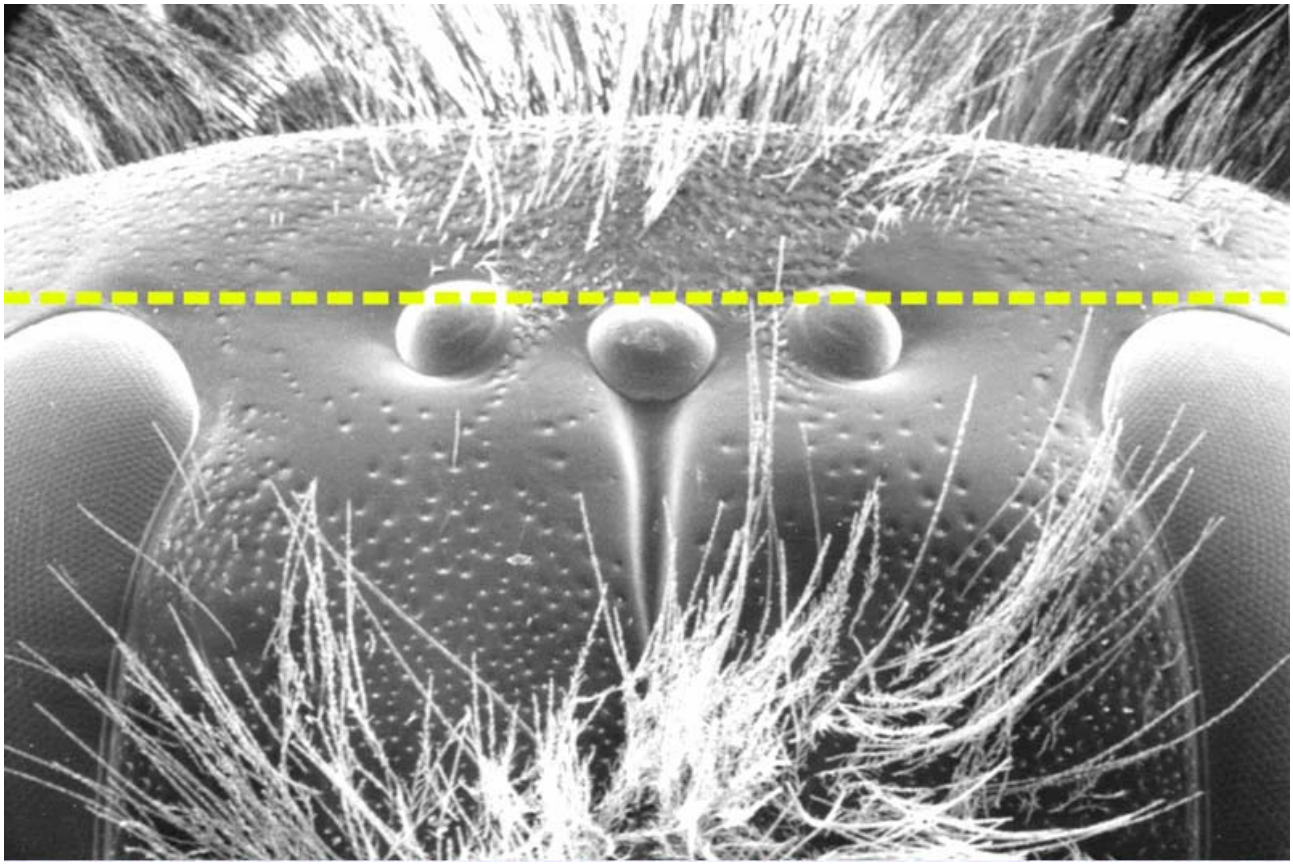


Fig. 18

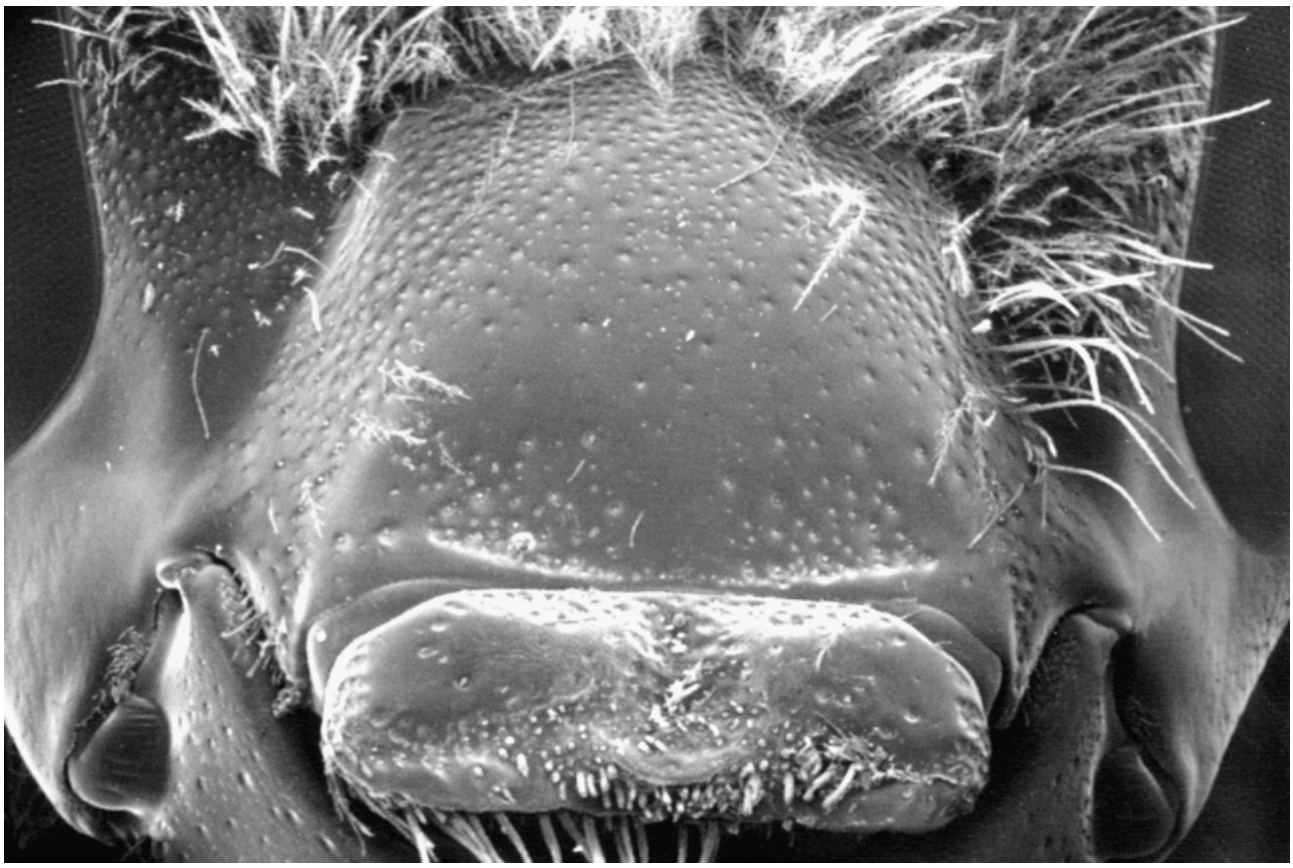


Fig. 19

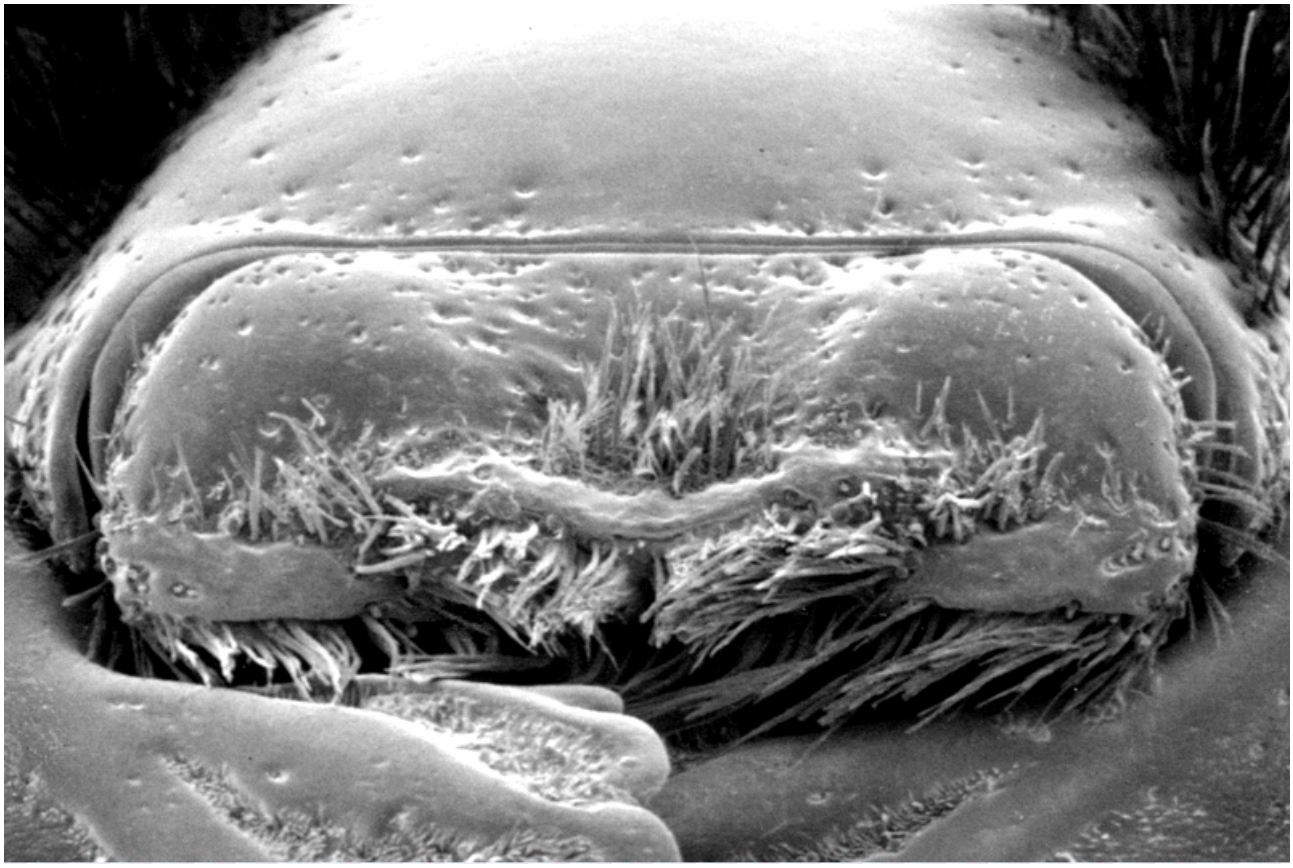


Fig. 20

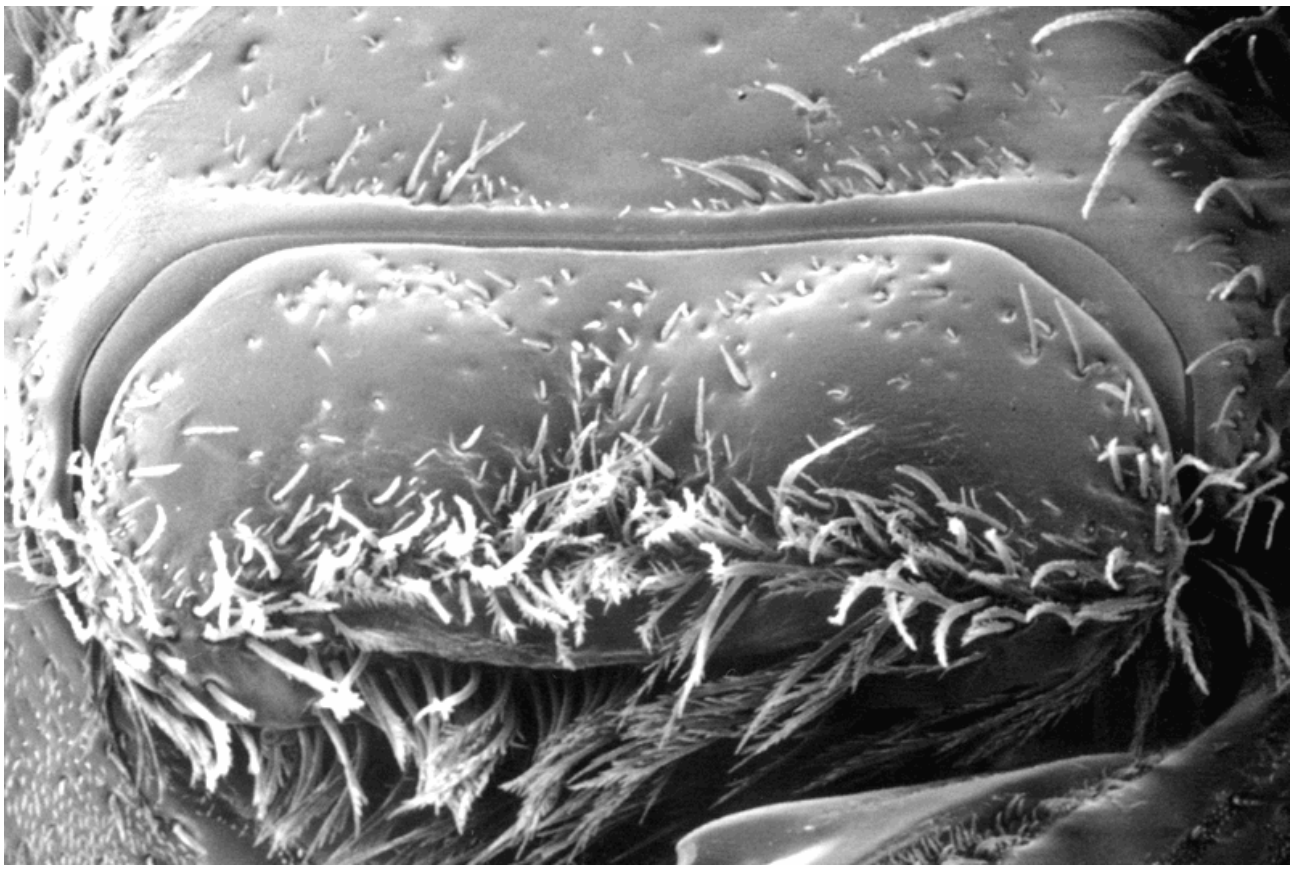


Fig. 21

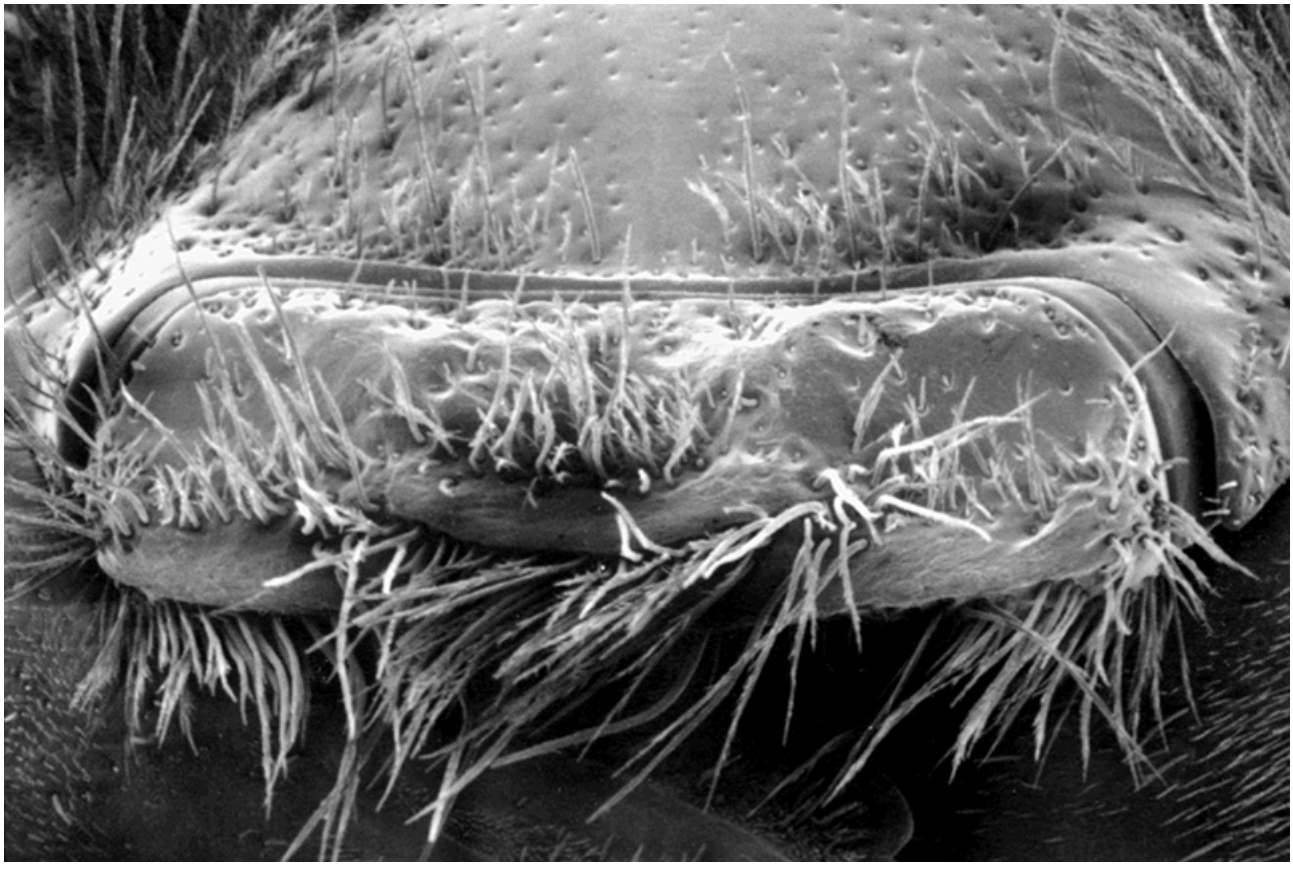


Fig. 22

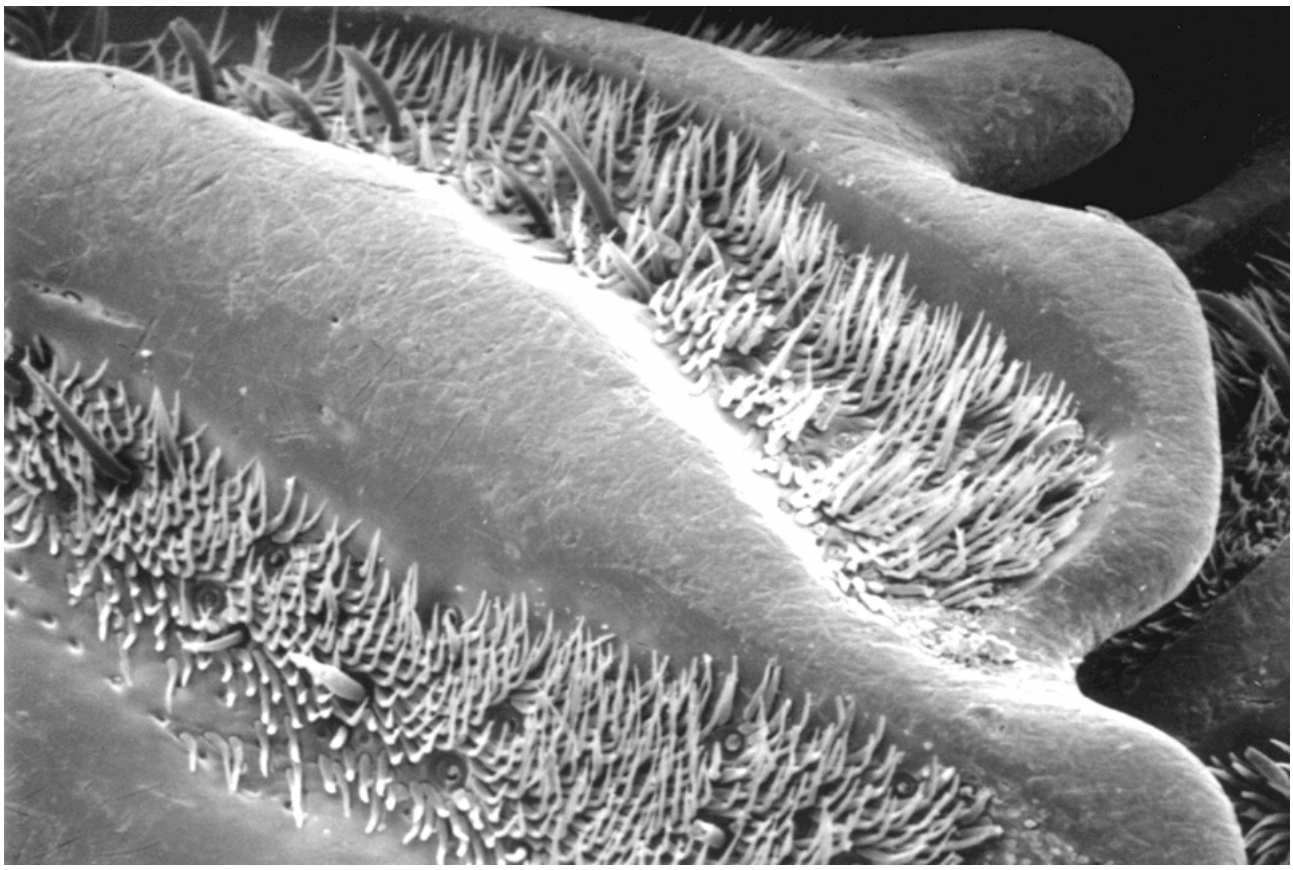


Fig. 23

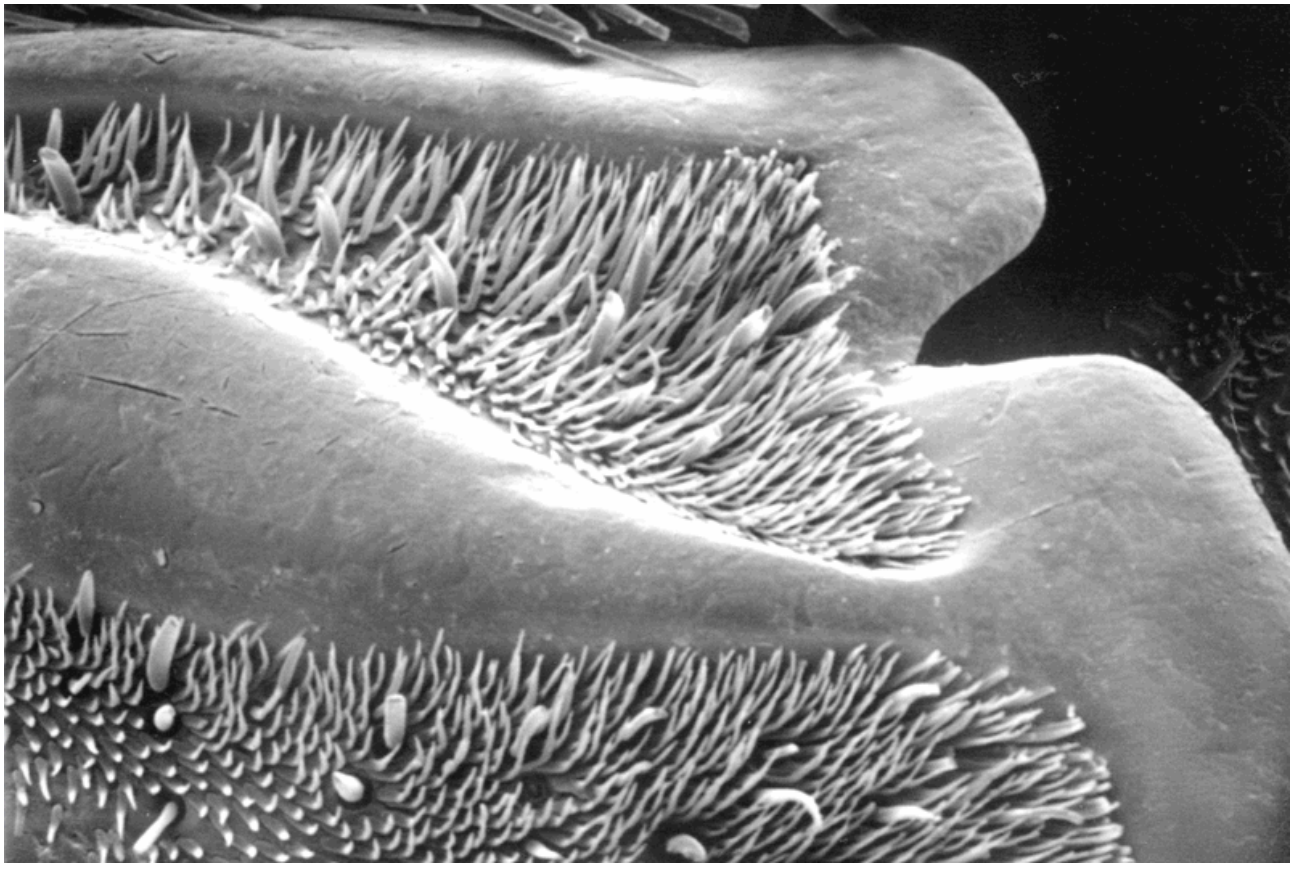


Fig. 24