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The Fine Structure of the Stridulatory Apparatus of the Water Scavenger Beetle *Regimbartia attenuata* (FABRICIUS) (Coleoptera, Hydrophilidae)

Nobutaka WATANABE

Department of Natural History, Graduate School of Science,
Tokyo Metropolitan University, Hachioji, Tokyo, 192–0397 Japan

Abstract The stridulatory apparatus of adult *Regimbartia attenuata* (FABRICIUS, 1801) was observed using scanning electron microscope, based upon specimens from Chiba Prefecture, in the Kanto area (Japan) to describe in detail the fine structure, and to compare it with those of some Japanese species of the genera *Berosus* LEACH and *Laccobius* ERICHSON. The plectrum (on the inner face of the elytron) is almost ellipsoidal in shape but often tapering anteriorly, and it is composed of a large number of minute cusps which are very close-set (7.6–13.4 cusps/100 μm^2) near the center. The pars stridens (on the laterosternite 3 of the abdomen) may be subdivided into the denticulated area, the ridged area and the region posterior to the ridged area. The ridged area is composed of 39–55 ridges, which are of the continuous eulamellated type. Sexual dimorphism is discernible: the mean number of the ridges in the female is significantly larger than in the male, but the functional significance is not clear at present. A process leading to the ridge through various denticulations is supposed: it is almost coincident with the course B proposed by MAILLARD and SELLIER (1970). Various characters in the plectrum, the denticulated area and the ridged area are more or less species-specific, but they also indicate some generic traits.

Introduction

In a considerable number of hydrophilids the stridulatory apparatus, which functions through the abdomino-elytral method (DUMORTIER, 1963), has been examined chiefly as to location, structure and stridulatory mechanism, and less often regarding produced sounds. In the genus *Regimbartia* ZAITZEV, however, no detailed work on this field has, to my knowledge, been carried out, while in its allied genus *Berosus* LEACH one may encounter numerous articles in the entomological literature: for example, examining North American *Berosus*-species, VAN TASSELL (1965) recorded their stress sounds (disturbance chirps of ALEXANDER (1967) (RYKER,1972)) and premating sounds (tremolos) as spectrograms, suggesting that the latter may function as an isolation mechanism in this genus. (See also for *Berosus*, BROCHER, 1912; DUMORTIER, 1963; MAILLARD, 1969; MAILLARD & SELLIER, 1970; OLIVA, 1992.)

The difficulty of perceiving stridulation by the human ear in the major parts of hydrophilid species examined has been mentioned (MAILLARD, 1969). In *Laccobius* sound emission has been ascertained by some authors (*e.g.*, VAN TASSELL, 1965; SCHELOSKE, 1975; PIRISINU *et al.*, 1988), whereas, in my experience, no stridulation has usually been perceptible in the laboratory, probably owing to the feebleness. Also in *Regimbartia attenuata* (FABRICIUS, 1801) there is no clear evidence for sound production, but it possesses the apparatus very similar in structure to those of *Berosus*, in which their chirps are so clear that they are detectable even at a distance from the sound source.

In this paper I intend to describe in detail the structure of the stridulatory apparatus of adult *R. attenuata* using scanning electron microscope (SEM), and to compare it with those of *Berosus*- and *Laccobius*-forms, which are provided with the ridged area within the pars stridens as in the species studied here, taking account of its evolutionary trends and taxonomical implications.

Material and Methods

The adult specimens examined were collected at a locality in the Kanto Plain, on the main island of Japan, Honshu, by the author himself, all being preserved in 60% ethanol (detailed collectig data: Hiraga, Inba-gun, Chiba-ken Prefecture, September 12, 1995).

For scanning electron microscopy (SEM), after cleaning in several ways including soaking in 5% KOH solution (at room temperature) and sonication, the elytra and the laterosternites were dehydrated using an ethanol series, transferred to t-butanol (at 26–30°C), subsequently dried using a freeze-drying device. The dried samples were mounted on stubs, sputter-coated with gold, and examined/photographed through a JEOL JSM–5300 SEM nearly always at 10 kV.

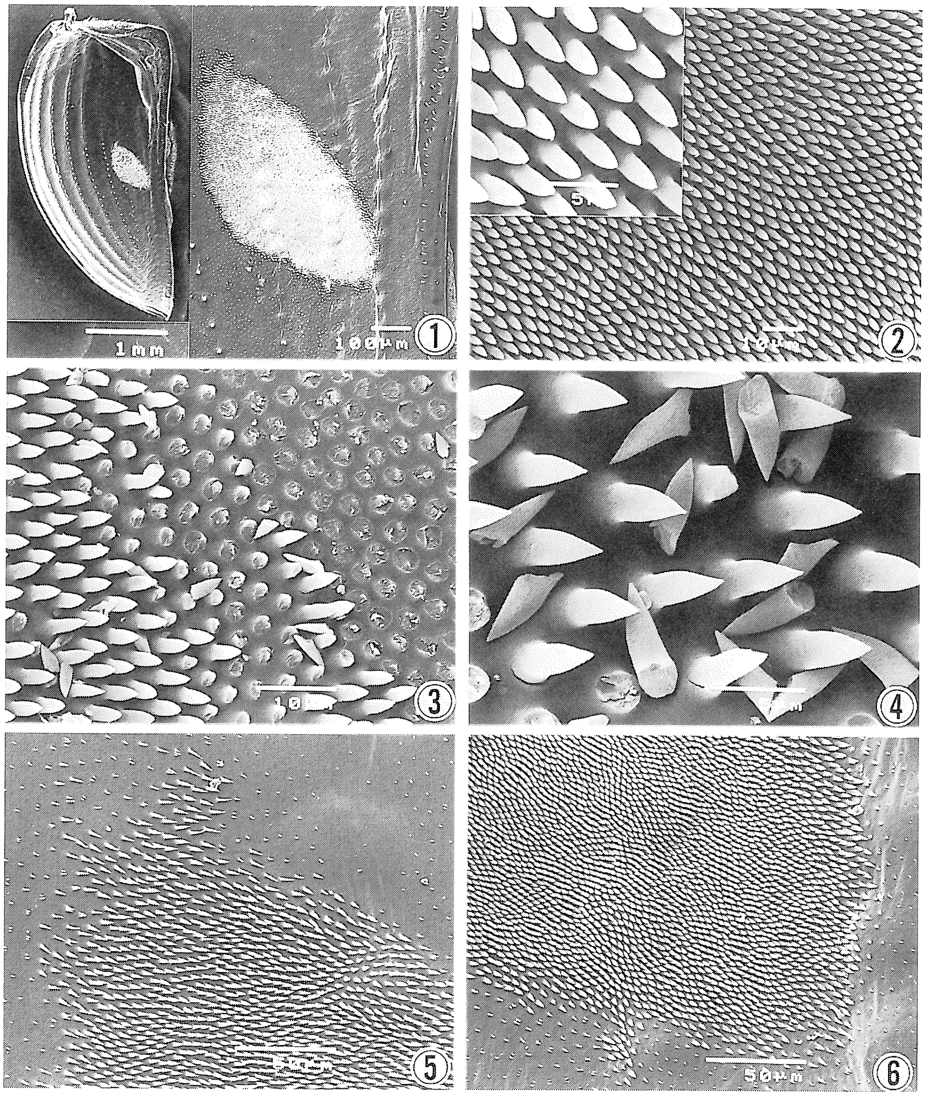
I mainly followed DUMORTIER (1963), VAN TASSELL (1965) and PIRISINU *et al.* (1988) in adopting morphological terms used here.

Observations

Plectrum. The plectrum (Figs. 1–6) is located on the inner face of the elytron, just at the middle of the entire length, and at cr. 7/10 of the elytral width from the elytral suture (Fig. 1). It is somewhat brownish in color, a little more raised than the elytral ground.

It is almost ellipsoidal in shape but often tapering anteriorly, with its inner contour more rounded than the outer one (Fig. 1). The long axis is at an angle of 30–40° to an axis through the elytral shoulder and the apex, cr. 2.2 times as long as the short one, having cr. 1/5 of the whole length of the elytron (Fig. 1).

The plectrum is composed of a large number of minute cusps (Figs. 2–4), which appear to be arranged wavily. Cusps are usually more or less decumbent, apical direc-



Figs. 1–6. Plectrum (left) of *Regimbartia attenuata* (FABRICIUS) (male). —— 1, Plectrum as a whole on inner face of elytron; 2, cusps of plectrum near central portion, with larger magnification; 3, 4, cusps artificially broken off, their shape in cross-section across base and form in various aspects becoming clear; 5, 6, cusps, near anterior and posterior ends, respectively, of plectrum, showing their successive transformation.

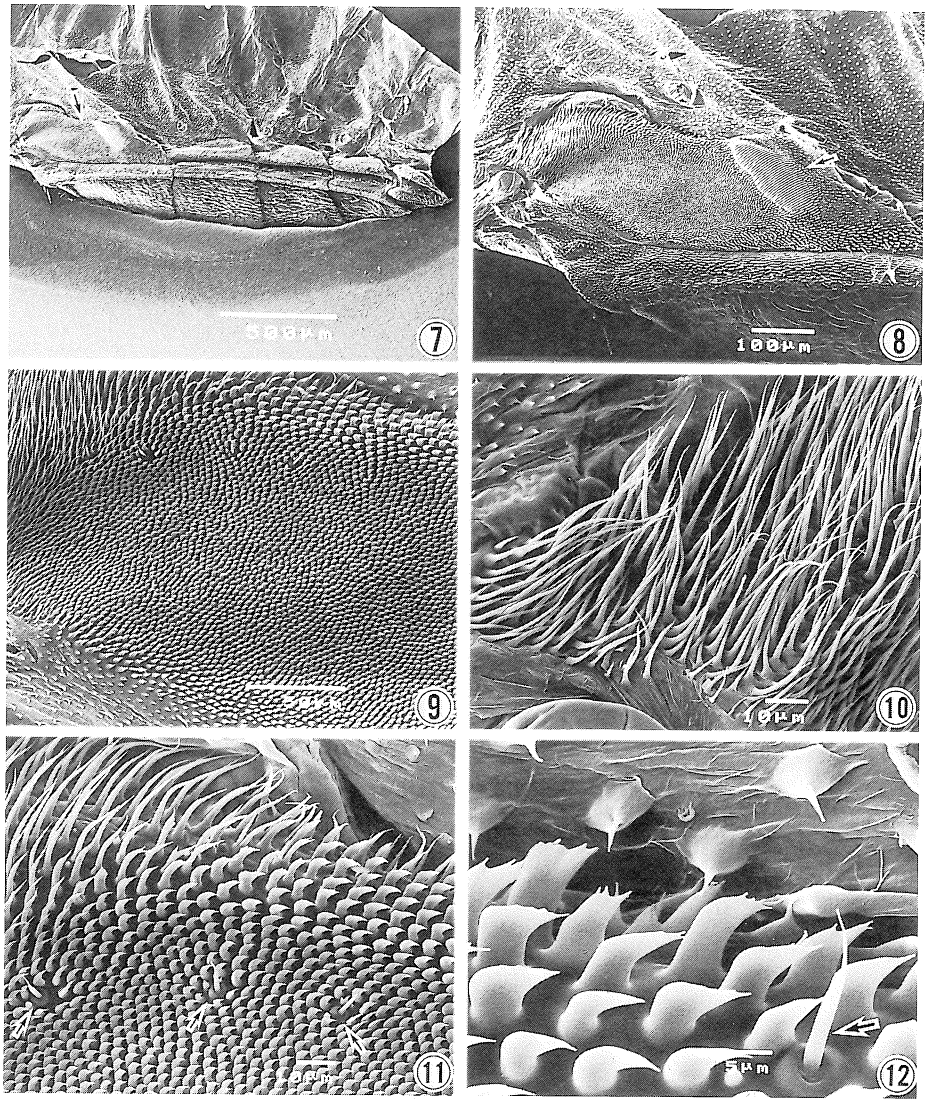
tions of cusps fluctuating successively between the lateral edge of the elytron and the elytral apex. The most crowded portion is fairly ample, being eccentrically situated toward the elytral suture on the posterior half of the plectrum, where the density is

7.6–13.4 cusps/100 μm^2 (Fig. 2). Each cusp in its typical form is circular in cross section across the base, feebly constricted near the base, then a little depressed after there, becoming roundedly sharpened gradually toward the apex (Figs. 3, 4). Cusps gradually become sparser, more variably modified (usually slenderer in shape and smaller in size) toward the peripheral portion of the plectrum, being eventually merged into the usual denticulation on the elytral ground (Figs. 5, 6).

Pars stridens. The pars stridens (Figs. 7–24) is located on the laterosternite 3 (Fig. 7), and may be subdivided into the denticulated area, the ridged area and the region posterior to the ridged area (Fig. 8). (Denticulated area; Figs. 9–18) Usual long hairs are crowded in the anterior part (Fig. 10), but they become rather abruptly shorter toward the ridged area to transform into falcate or hook-like processes (Fig. 11). Along the superior edge of the sclerite, however, the state of transformation is more variable: for example, hairs with the dichotomous tip, bill-like processes bearing the mono- or polydenticulated top are found there (Figs. 11–14). (Ridged area; Figs. 19–22) The area is nearly ellipsoidal in shape, situated at cr. 3/5 of the entire length from the anterior end of the laterosternite, near the superior edge of this sclerite. The long axis is at an angle of 38–56° to the longitudinal one of the insect body, and 1.5–2.3 times as long as the short axis (including the short ridges). About 39–55 ridges are countable (see also concluding remarks) but this counting is somewhat difficult near the anterior (Fig. 20) and posterior (Fig. 24) ends, where they are often incomplete, interrupted or irregularly subdivided. Ridges are placed along the short axis of the area, almost parallel to each other, and at subequal intervals (3.2–3.9 μm in the central part). Each ridge is cr. 1.0–1.4 μm wide near the center. Short ridges (Figs. 19, 21, 22, 24) are also present around major ones, but both are not in a line usually. The area is comparatively well-defined, but in peripheral parts it has also transitional zones to other areas: the transition proceeds abruptly in the apical part (Fig. 20), but gradually near the posterior end (Fig. 24) where ridges are successively changed into crest-like, multidentate or triangular minute processes and so on toward the inferior edge. Laterally, however, this is not always found especially at the side of the inferior edge (Fig. 21). (Region posterior to ridged area; Figs. 23, 24) The denticulation in this region is fairly sparser than in the denticulated area, the sparsity being notable posteriorly, near the superior edge of the sclerite.

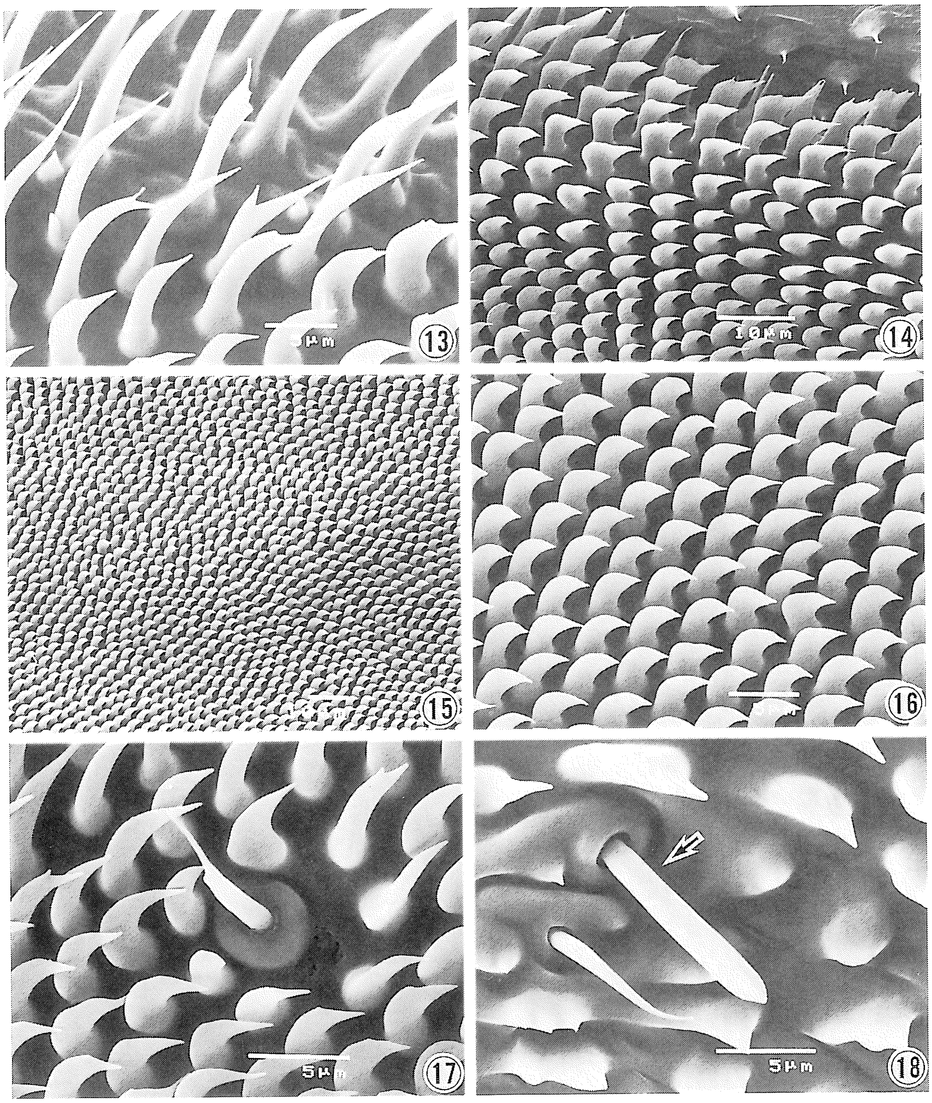
Sensilla. There are at least 14 conspicuous sensilla (Figs. 11, 12, 17, 18) within and near the portion which probably functions as "the pars stridens": the presence may be detectable by the disordered arrangement in denticulation except within the site covered with long hairs (Figs. 9, 10). Similar sensilla have already been reported (MAILLARD & SELLIER, 1970 (*Laccobius*); RYKER, 1972 (*Tropisternus*)).

They all possess a marked rim of the socket, being assigned to the following two types: one (Figs. 11, 12, 17) is shorter and suddenly narrows near the apex, to which almost all of them belong, whereas the other (Fig. 18) is longer, stouter and needle-like. The former sensilla are found along the superior edge of the sclerite within the principal part of the denticulated area except for several which are scattered more in-

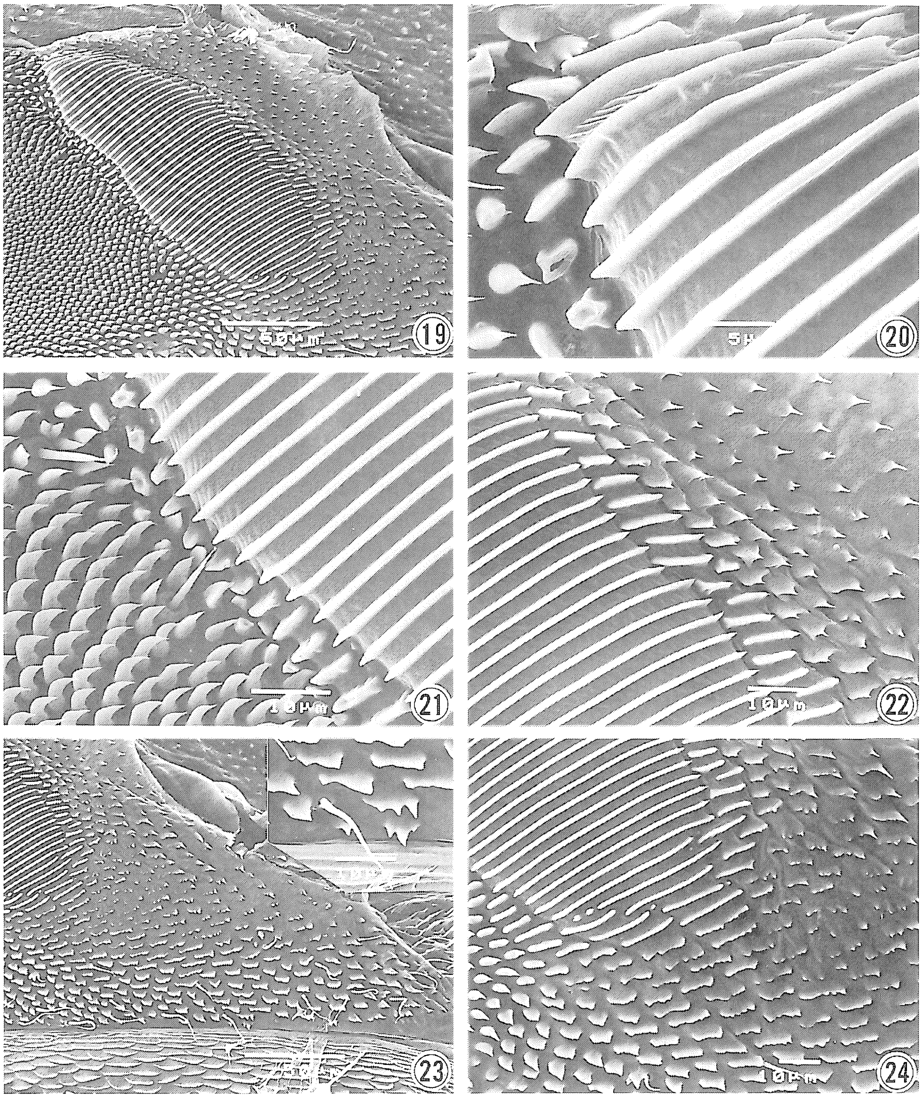


Figs. 7–12. Laterosternites (left) and pars stridens (left) of *Regimbartia attenuata* (FABRICIUS) (male). —— 7, Abdomen, showing laterosternites (arrow points to laterosternite 3); 8, laterosternite 3, showing pars stridens with ridged area (arrow); 9, denticulation near central portion in denticulated area; 10, anterior part in denticulated area, showing covering of hairs; 11, 12, denticulation along superior edge of this sclerite, showing their various transformations (arrows point to sensilla).

ward near the ridged area, whereas a sensillum of the latter lies somewhat apart from there. Still another needle-like sensillum is found, but it is situated near the anterior end of this sclerite, apparently outside the pars stridens.



Figs. 13–18. Denticulated area in pars stridens (left) of *Regimbartia attenuata* (FABRICIUS) (male). —— 13, Transitional zone of site covered with hairs or hook-like denticulations; 14, denticulation near superior edge of this sclerite, showing hook-like or bill-like micro-processes; 15, 16, hook-like denticulation near central portion; 17, sensillum within pars stridens; 18, needle-like sensillum (arrow) between ridged area and inferior edge of this sclertie.



Figs. 19–24. Pars stridens (left) of *Regimbartia attenuata* (FABRICIUS) (male). —— 19–22, Ridged area; 23, 24, region posterior to ridged area. —— 19, Ridged area as a whole; 20, anterior part of ridged area, showing abrupt transition; 21, lateral side of ridged area, with various denticulations; 22, lateral side of ridged area, with shorter ridges; 23, whole region posterior to ridged area, with larger magnification near inferior edge; 24, transitional zone near posterior end of ridged area, showing gentle successional change.

Concluding Remarks

The difference between the right and left stridulatory apparatus in *Regimbartia attenuata* is trivial even in quantity, both almost exactly being in mirror-image to each other. A sexual dimorphism is present: the difference in the mean number of ridges was statistically significant between the two sexes (♂: 44.00 (the mean)$\pm$1.23 (the standard error of the mean), $n=10$; ♀: 48.90$\pm$0.99, $n=10$. $t=-3.100$, $P=0.006$, on the left laterosternite 3, with an independent-samples t test), but the functional significance is not clear at present.

Ridges in this species are of the continuous eulamellated type, which has been defined by MAILLARD and SELLIER (1970) together with two other types, the discontinuous eulamellated and the polylamellated. Judging from the transition in the denticulation area, it may be supposed that a process leading to the ridge was as follows:

Through hook-like and bill-like denticulations and somewhat irregular lamellae, usual hairs — more or less long and lightly decumbent backwards, and nearly the same as those on ordinary laterosternites 4–7 in appearance — were transformed into a longer lamella by some morphological events including their lateral depression, shortening, elongation at the lateral side and coalescence. The process is almost coincident with the course B, which has been proposed by MAILLARD and SELLIER (1970) based upon *Berosus signaticollis* CHARPENTIER and others, though usual hairs eventually come to the same end also through another course A.

Compared the apparatus of *R. attenuata* with those of some Japanese species of *Berosus* LEACH (*lewisius* SHARP, *elongatulus* JORDAN, *signaticollis punctipennis* HAROLD, *japonicus* SHARP and *pulchellus* MACLEAY) (author's unpublished data) and *Laccobius* ERICHSON (*oscillans* SHARP and *fragilis* NAKANE) (ditto), the following became evident.

The plectrum as a whole and cusps are more or less species-specific in shape, but also show some generic traits, though the distribution of the different forms of structure of the stridulatory apparatus never squares with the systematic divisions in Coleoptera, unlike Orthoptera and Homoptera (DUMORTIER, 1963): in *Berosus* the anterior part of the plectrum is not much pointed unlike in *R. attenuata*, and the shape in contour considerably differs from species to species, while in *Laccobius* it is very elongate anteriorly, and subtly differs between the two species; in *Berosus* the cusp is usually with a more sharpened tip than in *R. attenuata*, but in *Laccobius* above-mentioned species are fairly different from each other in that *fragilis* possesses cusps each with a minute tip at the extreme end instead of a simple end. Also in the pars stridens the situation is similar in the plectrum: the ridged areas of *Regimbartia* and *Laccobius* are relatively smaller than in *Berosus*; the long axis of the area lies almost at right angles to the running direction of ridges in *Regimbartia* and *Berosus*, but in *Laccobius* the axis is almost parallel with their directions; the denticulated area is much crowded, the denticulation becomes hook-like near the ridged area in *Regimbartia*, but in *Berosus* it is sparser, not so denticulated, and in *Laccobius* it is close, gradually becoming blade-like toward the ridged area; the anterior site covered with long hairs is fairly conspicuous in *Regimbartia* and *Laccobius*, whereas it is completely absent in *Berosus*.

The laterosternite 2 is obscure, and not specialized in *Regimbartia*; in *Berosus* it is larger and provided with a similar denticulation to the sclerite 3, but it is indistinct whether this sclerite is asssociated with sound emission or not; in *Laccobius* it is larger again and with conspicuous processes, but other ordinary laterosternites 4–7 are also markedly denticulated instead of being covered with common hairs as usual on these sclerites.

The true range of the pars stridens is not clear except for the ridged area, but it seems that the denticulated area is also responsible for stridulation, as pointed out by PIRISINU *et al.* (1988), because species with the latter area alone also stridulate (*e.g.*, *Enochrus japonicus* (SHARP) and *Hydrochara affinis* (SHARP) (author's observations); *Tropisternus* spp. (RYKER, 1972)). In this context the distribution of the sensilla on this sclerite might become a clue to answer the question. It is probable that they are at least mechanically sensitive, but their detailed function is unknown.

要　　約

渡辺信敬：マメガムシの発音装置の微細構造. —— 千葉県産マメガムシ *Regimbartia attenuata* (FABRICIUS, 1801)の成虫を対象として，その発音装置(stridulatory apparatus)の微細構造を走査型電子顕微鏡の観察にもとづいて記述するとともに，その形質進化や分類学的価値についても考察した．本種の発音装置は，他のガムシ類同様に，腹部―翅鞘型に入り，（翅鞘は固定されたままで）腹部が動かされることによって音を発すると思われる．弦部(plectrum)は翅鞘内面上，外縁付近にあり，摩擦部(pars stridens)は第3側腹板(laterosternite)上に位置する．弦部は楕円形に近いが，前端部でしばしば尖った形状をとり，その長軸は，翅鞘肩部―翅端部を通る軸に対し30–40°傾斜している．また，この弦部は多数の微小尖突起(cusps)から成っていて，中央部付近では非常に密である(7.6–13.4箇/100 μm^2)．摩擦部は，3部分に分けることもできる（小歯状部域，隆起線部域，隆起線部域より後方の領域）．小歯状部域では，通常毛から嘴状，鎌状あるいは鉤状小突起へと変化していく状態が見てとれる．隆起線部域はほぼ楕円形で，その長軸はこの昆虫体の縦軸に対して38–56°傾斜，およそ39–55本の隆起線より成っているが，これらはほぼ平行，ほぼ等間隔に配置されている．この部域の後方では，小歯状突起はかなり疎らである．摩擦部内およびこの付近には，2種類の顕著な感覚器官が見られるが，その機能は未知である．

この発音装置の左右差は微小であるが，摩擦部の隆起線の本数には性的二型が認められ，雌の方がやや本数が多い．しかし，この機能上の意義は目下のところ判然としない．この隆起線は連続性真正薄板型(continuous eulamellated type) (MAILLARD & SELLIER, 1970)に入る．また，通常毛からこの隆起線へと至る筋道が推定されたが，それは鉤状あるいは嘴状小突起や幾分不規則的な薄板を経て，長い薄板へと至るものであり，上掲著者の提唱するBという筋道にほぼ一致する．本種と同型の（隆起線部域のある）装置を持つ2属，ゴマフガムシ属(*Berosus*), シジミガムシ属(*Laccobius*), の日本産種と比較した結果，弦部（全形および微小尖突起），小歯状部域，隆起線部域等では，多かれ少なかれ種特異的な形質が認められるが，属の特質もみられる場合

のあることが分かった．

第2側腹板は本種では明瞭ではないが，上記の別属ではともにかなり大きい．しかし，これが発音にかかわっているかどうかは定かではない．

摩擦部の真の範囲ははっきりしないが，この部分に関連する感覚器官の分布状態は，この問題を解く手掛かりとなるかもしれない．

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