中華昆蟲 16: 279-285(1996)
Chinese J. Entomol. 16: 279-285(1996)

# The Antennal Second Projection of Cixiidae (Homoptera: Fulgoroidea)

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## ABSTRACT

Scanning electron microscopy was used to examine the antennal 2nd projection of 36 species in 22 genera of Cixiidae. Two groups and 7 types have been recognized. Type 0 represents the absence of this character. The proposed evolutionary trend of Group 1 is Type 1→Type 2→Type 3. Yet, the relationships among the 3 types of Group 2, between the 2 groups, as well as between Type 0 and the 2 groups are unknown.

**Key words:** Cixiidae, evolutionary trend, 2nd projection.

## Introduction

When the antennal sensory plaque organs of Cixiidae were studied using a scanning electron microscope, a special structure was found at the apex of the original 3rd segment. Fennah (1975) described "antenna with segment 3 bearing a long flagellum and a long arista". "Segment 3 with arista about 5 times as long as segment". "The arista of antenna does not taper evenly, but is very narrowly tubular for about 60% of its length, then very abruptly to a fine filament". This is the only known reference to this small, neglected structure.

This structure is present in *Bothriocera diploreura* Fennah only as 3 conical protuberances, but is 5 times as long as the segment in *Confuga persephone* Fennah. In *Euphylonarthex phylostoma* Schmidt (Tettigometridae) the flagellum, except the original 3rd segment, is the projection of the original 3rd segment (Yang and Hsieh, 1994). It is considered to be another kind of projection and that is why it is called the 2nd projection in this paper. Up till now, the 2nd projection has been known throughout Cixiidae, except it is unrecognizable in *Duilius halinus* Uit. and *Euryphlepsia yamia* Tsaur et Hsu. Unfortunately its functions and histology are still not known.

## Materials and Methods

Dried specimens of 35 species of Cixiidae belonging to 22 genera (Table 1) were studied by scanning electron microscopy.

Whole dried specimens were boiled in 10% KOH for 10 min, then the antennae were removed in 75% ethanol and cleaned by sonification for about 10-15 sec. Finally, the specimen was dried in an acetone solution on a hotplate at 70℃.

The antennae of adults or nymphs were mounted on aluminum stubs with

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double-sided tape, coated with gold for 3 min in an Eiko EB-2 ion coater, and examined under a scanning electron microscope (Hitachi S-570) at an accelerating voltage of 15 kV.

## Results

Based on the observational data, 6 types of 2nd projection of Cixiidae are recognized as follows. The other ex-

Table 1. Observational data of the antennal 2nd projections (SP) of Cixiidae.

| Species(number examined) | Type | Length of SP.(um) | *Length of ap. in SP.(um) |
|---|---|---|---|
| *Duilius halinus* Uit.(3) | 0 | # | # |
| *Bothriocera diploreura* Fennah (2) | 1 | 1.3−1.4 | # |
| *Oliarus leporinus* (L.)(2) | 2 | 7.8−8.8 | 1.8−2.4 |
| *Benna formosana* (Nast)(3) | 2 | 14.7−15.8 | 2.4−7.3 |
| *Eumecurus longivertex* Kusnezov(1) | 3 | 9.6−11.2 | 1.2−2.4 |
| *Reptalus panzeri* (Low)(2) | 3 | 15.2−16.5 | 3.8−4.6 |
| *Pentastiridius pachyceps* (Mats.) Adult(5) | 3 | 16.9−20.0 | 3.8−4.5 |
| First instar nymph(3) | 3 | 12.4−18.4 | 3.6−4.2 |
| *Pseudoliarus aegyptiacus* Wag.(2) | 3 | 16.8−19.2 | 3.6−3.8 |
| *Mundopa kotoshonis* Mats. (1) | 3 | 22.8−24.7 | 4.2−4.8 |
| *Penthastira obscurus* (Signoret)(2) | 3 | 23.8−27.0 | 4.3−5.3 |
| *Oliarus tappanus* Mats.(2) | 3 | 24.8−27.1 | 4.8−5.6 |
| *Pentastiridius sudanicus* Lallemand(1) | 3 | 25.4−26.7 | 5.7−6.5 |
| *Achaemenes resurgens* (Walker)(2) | 3 | 28.8−30.6 | 4.7−5.8 |
| *Cixius nervosus* (L.)(2) | 3 | 30.3−31.5 | 3.9−4.7 |
| *Oliarus velox* Mats.(2) | 3 | 31.3−32.7 | 5.0−5.9 |
| *Aka gloriosa* Yang(1) | 3 | 34.1−37.2 | 3.4−4.0 |
| *Betacixius rinkihonis* Mats.(1) | 3 | 37.5−42.1 | 4.1−4.9 |
| *Betacixius michioi* Hori(2) | 3 | 40.0−42.4 | 5.6−7.2 |
| *Andes* sp. (2) | 3 | 40.2−42.3 | 3.1−3.9 |
| *Aka tasmami* Muir(1) | 3 | 40.8−43.4 | 3.4−4.2 |
| *Cixius maculosus* Tsaur and Hsu(2) | 3 | 41.6−44.4 | 11.0−12.2 |
| *Macrocixius giganteus* Mats.(2) | 3 | 42.6−47.5 | 5.5−6.3 |
| *Cixius circinatus* Tsaur and Hsu(3) | 3 | 45.2−46.3 | 8.2−9.1 |
| *Betacixius delicatus* Tsaur et Hsu(1) | 3 | 50.8−51.5 | 7.6−8.8 |
| *Andes formosana* (Mats.)(2) | 3 | 55.5−57.9 | 12.5−14.4 |
| *Kuvera communis* Tsaur(1) | 3 | 56.2−59.4 | 4.8−6.3 |
| *Oliarus polyphemus* Fennah Adult(2) | 3 | 60.5−63.9 | 6.2−7.5 |
| Fifth instar nymph(1) | 3 | 60.2−63.6 | 6.5−7.3 |
| *Cixius brochus* Tsaur and Hsu(3) | 3 | 62.6−65.9 | 5.8−6.3 |
| *Cixius tzuenus* Tsaur and Hsu(3) | 3 | 67.2−68.8 | 17.9−18.4 |
| *Trirhacus nawae* (Mats.)(1) | 3 | 70.5−72.4 | 9.0−11.2 |
| *Cixius yangi* Tsaur and Hsu(2) | 3 | 77.6−79.4 | 18.3−20.9 |
| *Pintalia* sp.(2) | 3 | 83.6−91.2 | 14.2−16.3 |
| *Oliarellus fulvus* Kusnezov(1) | 3 | >35.4 | 3.1−3.4 |
| *Borysthenes maculatus* (Mats.)(2) | 4 | 12.2−13.6 | # |
| *Borysthenes lacteus* Tsaur(1) | 5 | 13.6 | # |
| *Euryphlepsia yamia* Tsaur and Hsu(2) | 6 | # | # |

ap: apical part of 2nd projection.

#: represents SPs which are without forked apex or cannot be recognized.

amined species and their data are listed in Table 1.

### Type 0 (Fig. 1)

Petiole of original 3rd segment is short, not cleft. Main body of original 3rd segment is elongate ovate and dorsal surface is convex. Second projection is unrecognizable. Bourgoin's organ is present.

### Type 1 (Figs. 2, 10-1)

Petiole of original 3rd segment is short and one side not cleft. Main body of original 3rd segment is depressed, rounded, symmetrical, thickened at middle, gradually thinning to margin. One side of dorsal surface excavated. Base of 1st projection, Bourgoin's organ, and 2nd projection distributed at tips of a triangle; sides of latter 2 are shorter. Second projection is present as 3 small cones.

### Type 2 (Figs. 3, 10-2)

Petiole of original 3rd segment is relatively long, and one side not cleft. Main body of original 3rd segment is depressed, elongate ovate, assymmetrical, one side expanded. Dorsal surface is planar. Bases of 2 projections and Bourgoin's organ distributed at tips of a triangle, and sides of 2 projections are shorter. Second projection is composed of 3 processes of various lengths.

### Type 3 (Figs. 4,10-3)

Petiole of original 3rd segment is short, and one side not cleft. Main body of original 3rd segment is elongate ovate, not modified. Dorsal surface is convex. Bases of 2 projections and Bourgoin's organ distributed at tips of a triangle, and length of 3 sides are nearly the same. Second projection is composed of basal and apical parts, rather long. Basal parts cylindrical, not really segmented, surface sculptured. Apical part is composed of 3 filamental processes, each with varying or same lengths.

### Type 4 (Figs. 5, 10-4)

Petiole of original 3rd segment is rather long, and one side cleft. Main body of original 3rd segment is depressed, elongate ovate, assymmetrical, one side expanded, horizontal. Dorsal surface deeply excavated. Second projections and Bourgoin's organ are situated at middle of excavation. Second projection is cone-shaped with sculptured surface, rather long.

### Type 5 (Figs. 6, 10-5)

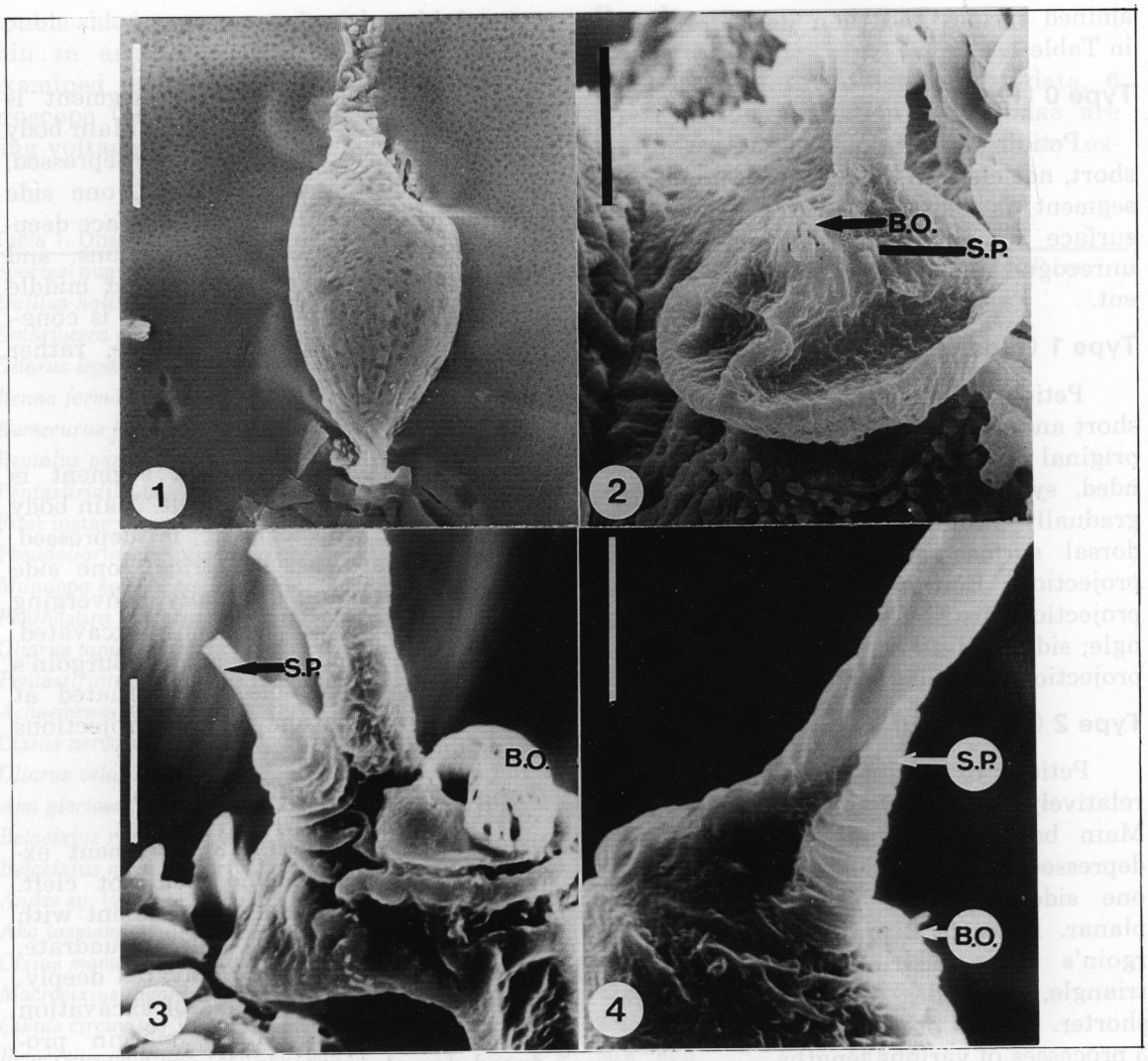
Petiole of original 3rd segment is rather long, and one side cleft. Main body of original 3rd segment is depressed, elongate ovate, assymmetrical, one side expanded, oblique, gradually converging to apex. Dorsal surface deeply excavated. Second projection and perhaps Bourgoin's organ (unrecognizable) are situated at middle of excavation. Second projections is irregular.

### Type 6 (Figs. 7, 8, 10-6)

Petiole of original 3rd segment extremely short, and one side not cleft. Main body of original 3rd segment with one side somewhat complex, quadrate, opposite side distinctly excavated deeply. Dorsal and lateral margins of excavation relatively reflect, ventral margin produced dorsolaterad into a relatively long process. Bourgoin's organ is situated at apex of unexcavated side. Second projection is unrecoganizable.

### Notes (Fig. 9)

When the antennal plaque organs of Delphacidae were studied using an electron microscope, a special structure was found in *Stenocranus longipenis* (Cortis). In this species the petiole of the original 3rd segment is short, and one side is not cleft. The main body of the original 3rd segment is not modified, having a convex dorsal surface. The base of the 1st projection, Bourgoin's organ, and the

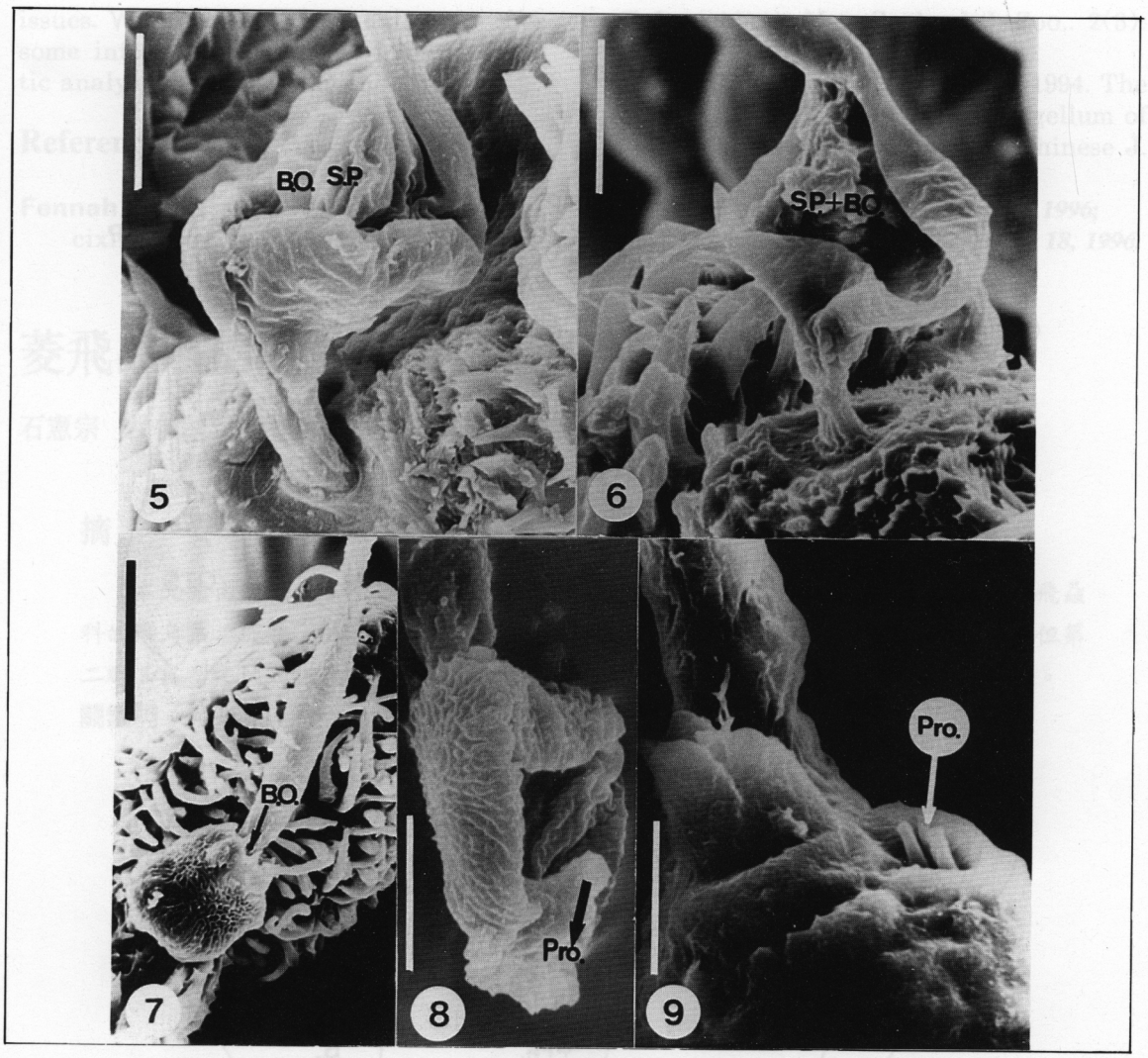



Figs. 1-4 Antennal 2nd projection of Cixiidae. 1. Type 0, *Duilius halimus* Uit. (Scale=20μm; 2. Type 1, *Bothriocera diploreura* Fennah (Scale=12.0μm; 3. Type 2, *Benna formosana* (Nast) (Scale=10μm; 5. Type 3, *Pseudoliarus aegyptiarus* Walker (Scale=10μm; B.O.=Bourgoin's organ; S.P.=Second projection.

special structure are distributed at the tips of a triangle, and the sides of the former 2 are shorter. The special structure produces from a pit as 3 short, terete processes. If the position and shape are considered, it should be the same as the second projection in Cixiidae. We do not know whether these 2 structures are homologous.

## Discussion

The 2nd projection of Cixiidae can be separated into 2 groups based on the shape. Group 1, including Types 1-3, is characterized by terminating in 3 processes. Group 2, including Types 4-6, may be characterized by the 2nd projection and Bourgoin's organ being situated in




Figs. 5-9 Antennal 2nd projection of Cixiidae. 5. Type 4, *Borysthenes maculatus* Yang (Scale=13.6μm; 6. Type 5, *Borysthenes lacteus* Tsaur (Scale=15.0μm; 7-8. Type 6; 7. dorsal view (Scale=27.0μm; 8. ventral view (Scale=12.0μm) 9. The processes of flagellum of *Stenocranus longipenis* (Cortis) (Scale=7.5μm; B.O.=Bourgoin's organ; Pro.=Process; S.P.=Second projection.

the excavation.

In Group 1, Type 1 has the 2nd projection appearing as 3 small cones. But in Type 2, it is separated into basal and apical parts. The length of the basal part is rather short, at only 5.2-7.9 μm. The apical part terminates with 3 filamental processes of varying or uniform length.

According to above data, among the 3 types of Group 1 seem having evolutionary relationships. The first projection (=flagellum) in *Euphylonarthex phylostoma* Schmidt (Tettigometridae) gradually becomes longer in each instar and is completely developed in the 1st instar throughout the Fulgoroidea except Tettigometridae (Yang and Hsieh, 1994). If

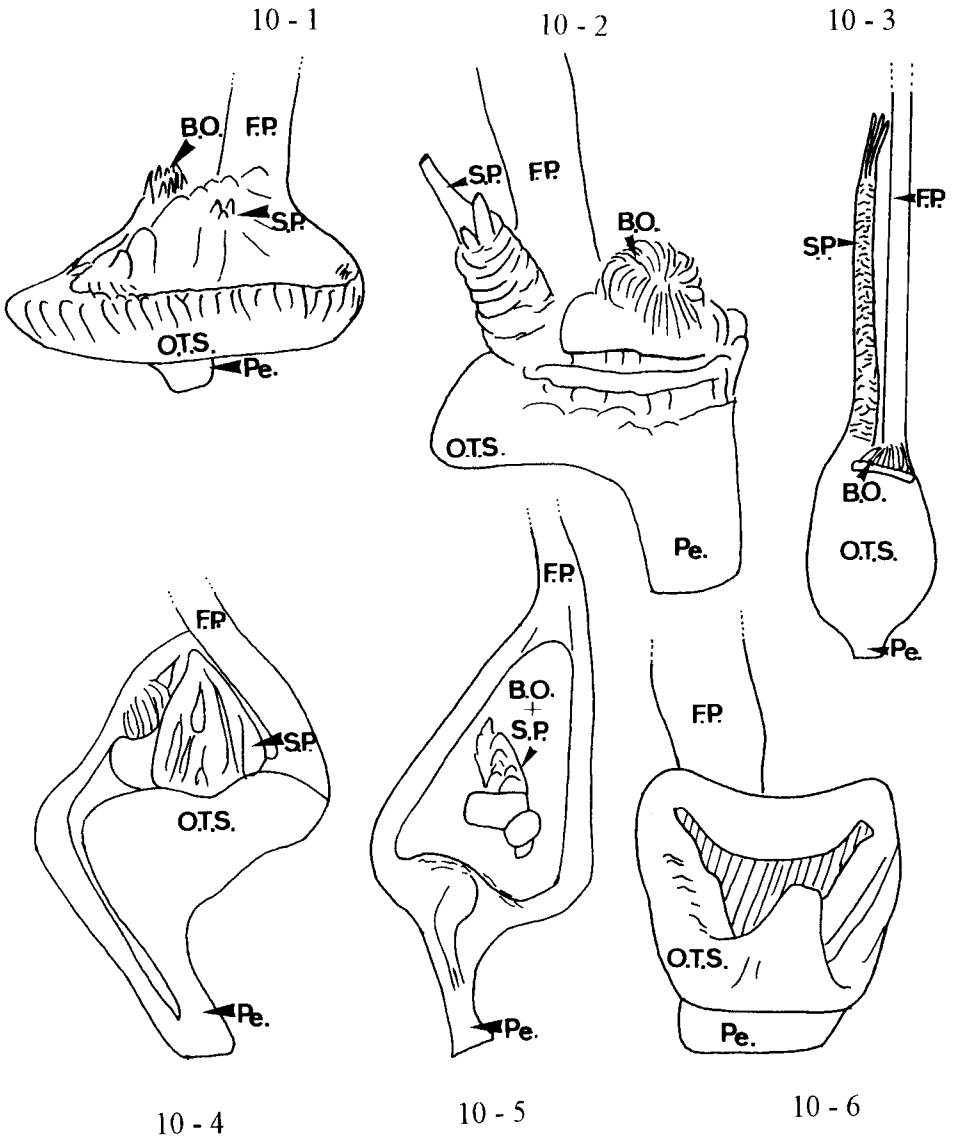



Fig. 10 Antennal 2nd projection of Cixiidae. 10-1. Type 1; 10-2. Type 2; 10-3. Type 3; 10-4. Type 4; 10-5. Type 5; 10-6. Type 6; F.P.=First projection; S.P.=Second projection; O.T.S.=Original 3rd segment; Pe.=Petiole; B.O. =Bourgoin's organ.

this case has any inferred value, then Type 1 may be the primitive character state, based on the basal part not being present yet; the apical part is composed of 3, small cones. Type 2 is the intermediate stage and the Type 3 is the advanced stage.

Unfortunately, among the 3 types of Group 2 there seems to be no clue by which to infer their evolutionary trend. The same situation occurs between Type 0 and the 2 groups.

Up till now, no phylogenetic work has been performed to resolve these

issues. We hope that these data may offer some information to assist in phylogenetic analysis of Cixiidae in the future.

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***Received for publication September 13, 1996; Revised manuscript accepted November 18, 1996.***

# 菱飛蝨科的觸角第二突起(同翅目：蠟蟬總科)

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## 摘　要

本文藉由掃描式電子顯微鏡共檢查菱飛蝨科36種22屬之觸角第二突起。得知菱飛蝨科的觸角第二突起，共有兩群、七型。第一群之進化趨勢推論為第一→二→三型。但第二群其三型之間的進化趨勢，及第零型、第一群與第二群三者之間的進化趨勢未明。

**關鍵詞**：同翅目，蠟蟬總科，稻蝨科，觸角，瓦楞感覺器。

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