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Antennal sensory plaque organs of the Cixiidae (Homoptera:Fulgoroidea)【Research report】

菱飛蝨科之觸角瓦楞感覺器(同翅目：蠟蟬總科)【研究報告】

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Abstract

Scanning electron microscopy was used to examine the antennal sensory plaque organs of 50 species in 29 genera of the Cixiidae. Two groups and 6 types of sensory plaque organs are recognized based on the morphology of the plaque and distribution pattern of plaques on the plate. Group 1 is composed of Types 1 to 3, whose planiform basally, then filiform apically. Group 2 is composed of Types 4 to 6, whose plaques are planiform throughout. Between the 2 groups, evolutionary trend is proposed as Group 1-> Type 2 -> Type 3; and within Group 2 as Type 4 -> Type 5 and Type 4 -> Type 6.

摘要

本文藉由掃描式電子顯微鏡共檢查菱飛蝨科50種29屬之觸角瓦楞感覺器。透過瓦楞突起的形態及其於板面上的分布位置，可發現瓦楞感覺器共有兩群、六型。第一群包含第一至第三型，它們的瓦楞突起為基部側扁，其後完全為絲狀形。第二群包含第四至第六型，它們的瓦楞突起為完全側扁。第一群三型之間的進化趨勢推論為第一→二→三型。第二群四型之間的進化趨勢不明。而第一與第二群之間的進化趨勢推論為第一群→第二群。

Key words: Homoptera, Fulgoroidea, Cixiidae, antennae, sensory plaque organs.
關鍵詞: 同翅目、蠟蟬總科、菱飛蝨科、觸角、瓦楞感覺器。

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Antennal Sensory Plaque Organs of the Cixiidae (Homoptera: Fulgoroidea)

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ABSTRACT

Scanning electron microscopy was used to examine the antennal sensory plaque organs of 50 species in 29 genera of the Cixiidae. Two groups and 6 types of sensory plaque organs are recognized based on the morphology of the plaque and distribution pattern of plaques on the plate. Group 1 is composed of Types 1 to 3, whose plaques are planiform basally, then filiform apically. Group 2 is composed of Types 4 to 6, whose plaques are planiform throughout. Between the 2 groups, evolutionary trend is proposed as Group 1 → Group 2; within Group 1 as Type 1 → Type 2 → Type 3; and within Group 2 as Type 4 → Type 5 and Type 4 → Type 6.

Key words: Homoptera, Fulgoroidea, Cixiidae, antennae, sensory plaque organs

Introduction

This is the 3rd part dealing with investigations of the sensory plaque organs of the Fulgoroidea. In past investigations, there was no information on this family except in Bourgoin and Deiss (1994), who pointed out, that in part of Cixiidae, plaques belong to the ridged type and star-shaped type.

This paper describes the different types of the antennal sensory plaque organs in the Cixiidae, and presumed evolutionary trends are proposed.

Materials and Methods

Investigations were carried out on 50 species in 29 genera of the Cixiidae by scanning electron microscopy (see Table 1 for a list of taxa examined). All examined specimens, including males, females, and nymphs, were placed in small vials containing 70% ethanol where they remained for at least 1 h. Whole specimens were soaked in 10% KOH for 15 min at 60 ℃, then their antennae were removed in 70% ethanol and cleaned by sonification for about 15-20 sec, and finally, dried in on acetone solution on a hot plate at 70 ℃.

The antennae of specimens were

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mounted on aluminum stubs with 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

In Cixiidae, no differences in diversity or distribution were found in sensory plaque organs among both sexes and nymphs. The distribution pattern of sensory plaque organs was unrelated to the total number of plaques. The total number of sensory plaque organs was also unrelated to the types. The sensory plaque organs of Cixiidae were examined for (1) the external morphology of plaque, (2) the transverse section of plaque, and (3) the distribution pattern of plaques on the plate. The transverse section of plaque was drawn through broken plaque. Based on the observed data, 2 groups and 6 types of antennal sensory plaque organs are recognized. All examined species and their morphological data for all 6 types are listed in Table 1.

Table 1. Sensory plaque organs of Cixiidae

Taxon (examined species)	Sensory plaque organs			Denticle Plaque	
	Type	No.	Diameter (μm)	No.	No.
Cixiinae					
Oliarus polyphemus Fennah (2) abc	1	16 - 18	28.3 - 57.2	4 - 10	8 - 17
Penthastira obscurus (Signoret) (1) a	1	16 - 18	20.3 - 33.6	5 - 10	6 - 12
Duilius halimus Uit. (3) b	1	20 - 31	17.2 - 26.8	4 - 8	4 - 12
Norialsus pretoriae (Syn.) (1) b	1	28 - 32	20.4 - 32.2	6 - 9	5 - 14
Trirhacus nawae (Mats.) (1) b	2	22 - 28	15.3 - 32.6	3 - 9	2 - 16
Bothriocerinae					
Euryphlesia cocos Muir (1) a	2	25 - 27	17.3 - 36.5	4 - 12	4 - 35
Cixiinae					
Cixius nervosus (Linn.) (1) bc	2	30 - 36	20.4 - 32.2	7 - 14	11 - 20
Bothriocerinae					
Euryphlesia yamia Tsaur & Hsu (3) a	3	21 - 27	11.3 - 44.5	4 - 12	4 - 35
Bothriocera diplorura Fennah (2) a	4	13 - 18	18.2 - 35.1	4 - 12	6 - 20
Borystheninae					
Borysthenes lacteus Tsaur (2) a	4	20 - 28	21.2 - 43.7	4 - 10	8 - 22
Borysthenes maculatus Tsaur (2) a	4	19 - 27	23.7 - 45.8	6 - 14	11 - 23
Cixiinae					
Oliarus tappanus Mats. (2) a	4	19 - 23	22.5 - 30.5	5 - 8	5 - 14
Cixius broncus Tsaur & Hsu (3) a	4	20 - 30	16.8 - 33.7	6 - 8	10 - 17
Reptalus panzeri (Low) (2) a	4	28 - 30	19.1 - 24.7	5 - 9	6 - 14
Oliarus leporinus (L.) (2) a	4	28 - 34	18.3 - 26.8	6 - 9	6 - 11
Oliarus velox Mats. (2) a	4	30 - 35	16.9 - 23.8	6 - 9	5 - 13

Table 1. (Continued)

Myndus kotoshonis Mats. (1) a	4	>10	13.7 - 21.6	5 - 9	6 - 10
Betacixius michioi Hori (2) b	4	19 - 23	16.0 - 30.9	3 - 7	3 - 11
Oliarus concolor Fieber (2) b	4	26 - 30	25.4 - 32.5	7 - 12	6 - 14
Hyalesthes flavipennis Horv. (1) b	4	29 - 30	20.0 - 32.5	5 - 10	6 - 10
Cixius vittatus Tsaur & Hsu (3) b	4	24 - 31	20.5 - 32.8	5 - 8	6 - 14
Cixius circinatus Tsaur & Hsu (3) b	4	31 - 40	13.0 - 23.9	6 - 9	8 - 14
Mundopa kotoshonis Mats. (1) b	4	>12	16.8 - 25.4	5 - 9	7 - 12
Betacixius rinkihonis Mats.(1) c	4	12 - 16	16.8 - 25.7	5 - 8	5 - 12
Betacixius clypealis Mats. (2) c	4	11 - 17	18.6 - 29.4	6 - 8	8 - 12
Kuvera taiwana Tsaur (1) c	4	17 - 23	16.9 - 28.3	5 - 7	8 - 12
Kuvera communis Tsaur (2) c	4	17 - 22	11.2 - 24.7	4 - 8	5 - 10
Cixius tzuenus Tsaur & Hsu (3) c	4	20 - 26	22.1 - 34.9	5 - 9	7 - 12
Kuvera similis Tsaur (1) c	4	26 - 28	14.2 - 27.5	5 - 7	7 - 12
Cixius maculosus Tsaur & Hsu (2) c	4	26 - 32	20.4 - 30.6	5 - 8	6 - 12
Kuvera transversa Tsaur (2) c	4	28 - 32	12.3 - 23.7	5 - 9	10 - 15
Tachycixius nawae (Mats.) (2) a	4	22 - 24	19.2 - 32.6	5 - 10	3 - 12
Oliarellus fulvus Kusnezov (1) a	4	>15	15.9 - 27.6	5 - 10	5 - 11
Pinacites calvipennis Emeljanov (1) a	4	>15	20.0 - 34.0	5 - 9	5 - 12
Eumecurus longivertex Kusnezov (1) a	4	>12	18.5 - 30.4	4 - 10	6 - 9
Pentastiridius pachyceps (Mats.) (5) b	4	14 - 16	19.9 - 32.6	6 - 12	5 - 16
Andes sp. (2) b	4	21 - 28	19.2 - 32.7	7 - 9	7 - 18
Pseudoliarus aegyptiacus Wag. (1) a	4	27 - 31	22.8 - 35.0	7 - 11	7 - 12
Cixius yangi Tsaur & Hsu (2) b	4	32 - 37	22.4 - 31.3	5 - 8	6 - 14
Brixia venusta Tsaur (3) b	4	32 - 43	21.8 - 30.5	6 - 10	6 - 18
Cixius mukwanus Tsaur & Hsu (3) c	4	15 - 23	18.2 - 33.5	5 - 8	6 - 12
Aka tasmami Muir (1) c	4	22 - 28	20.6 - 30.5	6 - 12	6 - 12
Aka gloriosa Yang (1) c	4	26 - 29	20.2 - 36.6	6 - 9	7 - 12
Macrocixius grossus Tsaur & Hsu (1) c	4	34 - 39	16.9 - 31.4	7 - 12	7 - 14
Koroana interior (Walker) (2) c	5	30 - 37	32.9 - 42.9	6 - 12	9 - 24
Andes formosana (Mats) (2) c	5	30 - 35	20.0 - 34.8	6 - 9	9 - 22
Achaemenes resurgens (Walker) (2) c	5	32 - 38	13.2 - 24.8	5 - 8	6 - 14
Pintalia sp. (2) a	6	16 - 18	23.5 - 39.6	4 - 10	9 - 18
Benna formosana (Nast) (3) a	6	26- 37	20.5 - 40.0	5 - 9	7 - 15

a: denticle is circular in transverse section.
b: denticle is irregularly circular in transverse section.
c: denticle is notched in transverse section.

Group 1

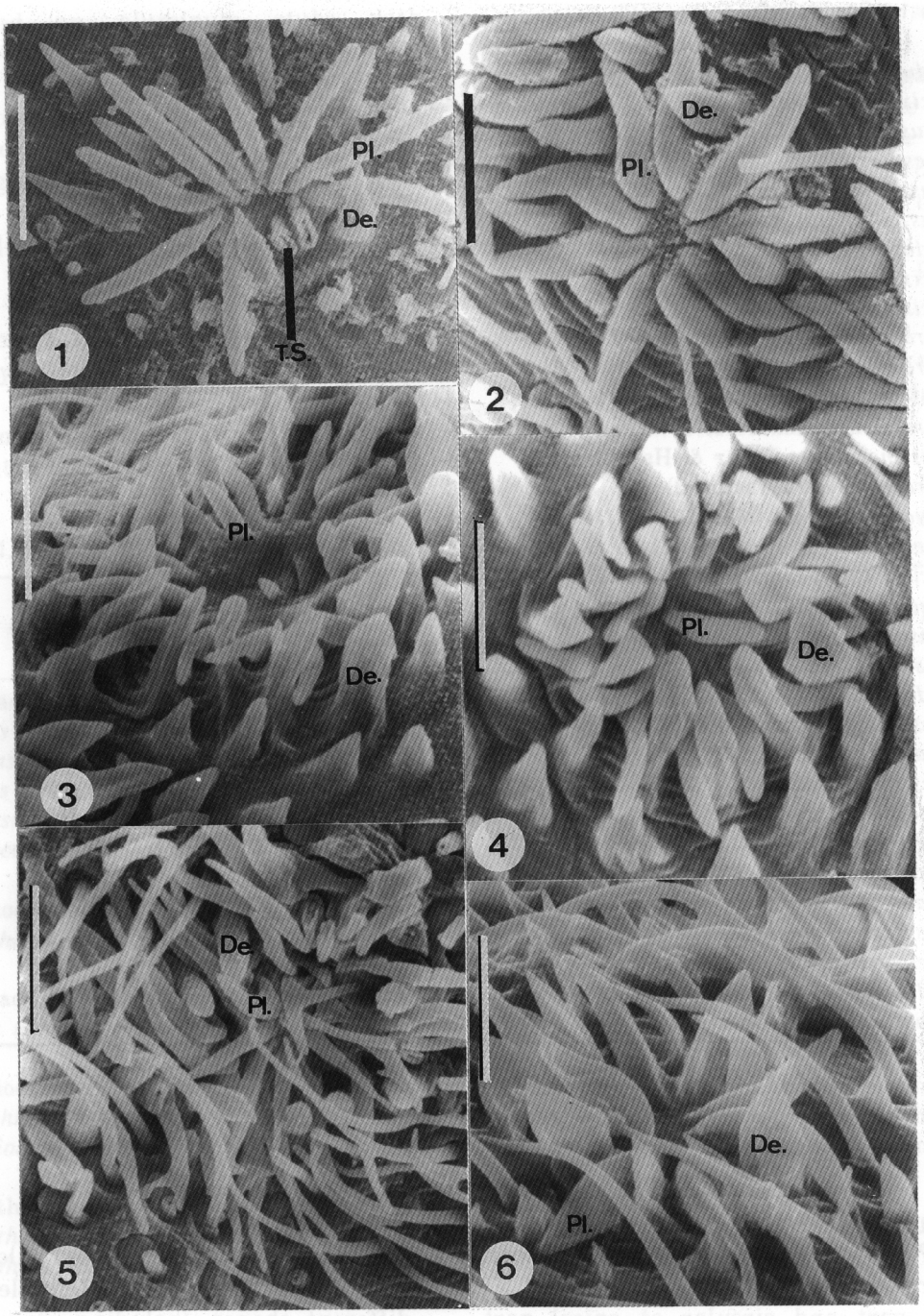
Plaque is planiform basally, then filiform apically. Plaque is oblong at basal part and circular at apical part in transverse section. Denticles erect throughout, acute, and not incurved at apex. Based on the distribution pattern of plaques on the plate, 3 types can be distinguished in Group 1.

Type 1 (Figs. 1, 2)

Plaques are distributed along the margin of the plate. Denticles have different shapes, including cone-shaped, irregularly cone-shaped and thin plate-shaped.

Type 2 (Figs. 3, 4)

Plaques are distributed on the margin and center of the plate. Denti-



Figs. 1-6. Sensory plaque organs of Cixiidae. 1 - 2. Type 1; *Oliarus polyphemus* Fennah (Scale=20 μm); 2. *Penthastira obscurus* (Signoret) (Scale=15.0 μm); 3-4. Type 2, *Cixius nervosus* (L.) (Scale: 3=17.6 μm, 4=15.3 μm); 5. Type 3, *Euryphlepsia yamia* Tsaur and Hsu (Scale=15.0 μm); 6. Type 4, *Aka gloriosa* Yang (Scale=12.0 μm). C.r.=Cuticular ring; De. =Denticle; Pl.=Plaque; T.s.=Transverse section.

cles erect throughout, acute, and not incurved at apex. Denticles have different shapes, including cone-shaped, irregularly cone-shaped, and thin plate-shaped.

Type 3 (Fig. 5)

Plaques are distributed over the entire plate. Denticles cone-shaped.

Group 2

Plaque is planiform throughout. In transverse section, plaque is completely oblong. Based on the distribution pattern of plaques on the plate, 3 types can be distinguished in Group 2.

Type 4 (Figs. 6, 7)

Plaques are distributed along the margin of the plate. Denticles erect throughout, acute, and not incurved at apex. Denticles have different shapes, including cone-shaped, irregularly cone-shaped, and thin plate-shaped.

Type 5 (Fig. 8)

Plaques are distributed all over the plate. Denticles erect throughout, acute and not incurved at apex. Denticles are thin plate-shaped.

Type 6 (Fig. 9)

Plaques are distributed over the entire plate. Denticle is cone-shaped. Apex of denticle turns toward the central area of plate.

Discussion

Chen and Yang (1995) pointed out that "The Delphacidae, Meenoplidae, Kinnaridae, Cixiidae, Achilidae, Achilixiidae and Derbidae compose the Cixiidae-group". In the Cixiidae-group, the plaque is filiform (Shih and Yang, 1996) or is transformed (Wilson, 1989; Bourgoin and Deiss, 1994, Figs. 11, 12; Cheng and Yang, 1996).

As to the distribution pattern of plaques on the plate of the sensory plaque organ, the marginal distribution pattern is commonly present in the Cixiidae-group (Cheng and Yang, 1996); the well-proportioned distribution pattern is only present in Delphacidae and Cixiidae. Yet, the plaque has 2 different morphologies in Cixiidae: (1) planiform basally, then filiform; and (2) planiform throughout. In the Delphacidae, the plaque is completely filiform (Shih and Yang, 1996). According to the out-group comparisons (Watrous and Wheeler, 1981) and the intra-group repartition criterion (Wiley, 1981), those plaques which are the marginal distribution pattern should be considered as the primitive character state in Cixiidae and the well-proportioned distribution pattern as an advanced character state.

In this study, the antennal sensory plaque organs of Cixiidae can be separated into 2 groups, which contain 6 types based on the morphology and distribution pattern of the plaques. Herein, the inner surface of each sensory plaque organ of all examined species is composed of a cuticular ring and many irregularly triangular pores (Fig. 10).

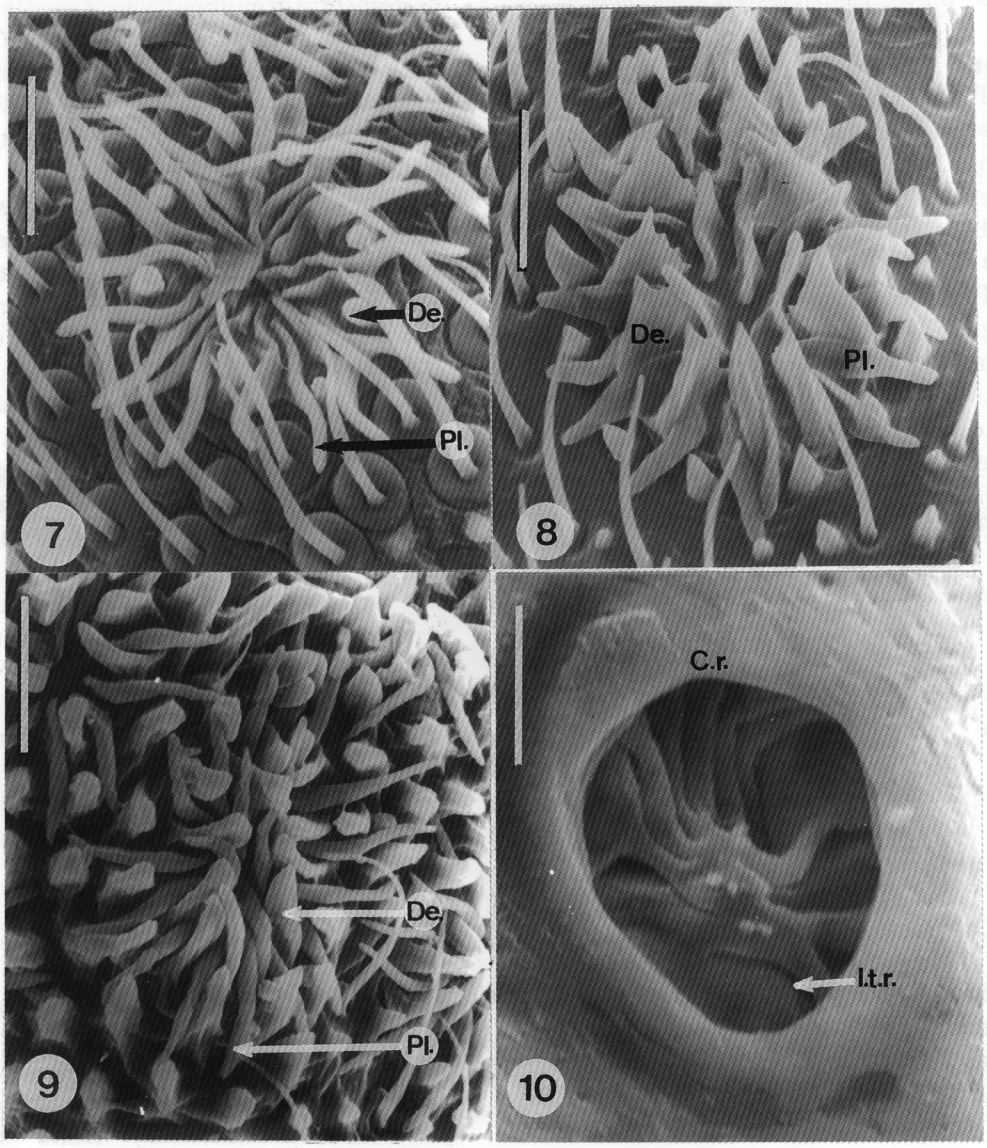
In Group 1, plaque is planiform basally, then filiform apically. In Group 2, plaque is planiform. The hypothetical evolutionary trend between these 2 groups is proposed to be Group 1 → Group 2.

Group 1 contain 3 types: (1) in Type 1, plaques are distributed along the margin of the plate; (2) in Type 2, plaques are distributed on the margin and center of the plate; (3) in Type 3, plaques are distributed over the entire plate. The evolutionary trend among the 3 types is proposed to be Type 1 → Type 2 → Type 3.

Group 2 contains 3 types: (1) in Type 4, plaques are distributed along the margin of the plate; (2) in Types 5

and 6, plaques are distributed over the entire plate. Based on above data, the evolutionary trend among the 3 types is proposed to be Type 4 → Type 5 and Type 4 → Type 6.

Furthermore, the morphologies of plaques are fairly uniform for most species in many given genera; for example, the genera Cixius, Euryphlesia, and Oliarus (Table 1). Concerning subfamilies in Cixiidae, plaques have no stable morphology (Table 1): (1) the Cixiinae is the largest subfamily, and its members have all 6 different types



Figs. 7-10. Sensory plaque organs of Cixiidae. 7. Type 4, *Bothriocera diploreura* Fennah (Scale= 15.0 μm); 8. Type 5, *Koroana interia* (Walker) (Scale=18.1 μm); 9. Type 6, *Pintalia* sp. (Scale=20.1 μm); 10. Inner surface of sensory plaque organs of *Norialsus pretoriae* (Syn.) (Scale=7.5 μm). C.r.=Cuticular ring; De. = Denticle; Pl.=Plaque; I.t.p.=Irregularly triangular pore.

except Type 3; (2) for 2 examined species of Borystheninae, both conformably belong to Type 4; (3) for 3 examined species of Bothriocerinae, Types 2, 3, and 4 are found.

In the present study, there is a confused and unsolvable phenomenon in antennal sensory plaque organs of Cixiidae, namely, denticles in different species of the same genus have no stable morphology, even within the same species. For example, the denticles in *Oliarus polyphemus* Fennah have different shapes, including cone-shaped, irregularly cone-shaped and thin plate-shaped. This condition implies that the denticles are not a suitable character for phylogenetic analysis within the Cixiidae.

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菱飛蝨科之觸角瓦楞感覺器（同翅目：蠟蟬總科）

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摘　要

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關鍵詞：同翅目、蠟蟬總科、菱飛蝨科、觸角、瓦楞感覺器

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