STRUCTURE OF THE OCCIPITAL REGION IN PIERIDAE (LEPIDOPTERA) FROM JAPAN

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Synopsis : The structure of the occipital region in the Pierid butterflies mainly from Japan was observed. As the result, *Leptidea* was separable from the other species by the form of occipital prominence. The others were divided into 2 groups and 4 subgroups. *Catopsilia* resembled very closely Pierinae while *Aporia* and *Anthocharis* are very similar to Coliadenae in the occipital structure.

INTRODUCTION

Previously the authors reported the structure of the occipital region in some families of Rhopalocera, such as Nymphalidae, Libytheidae and Papilionidae (TSUBUKI & KOYAMA, 1978, 1979).

Though a few papers were related briefly to the occipital structure of Pieridae (EASSA, 1963; TSUBUKI et al., 1975), detailed descriptions on it have not been performed up to the present.

Then the authors studied the occipital form of 26 species in 12 genera belonging to Pieridae occuring mainly from Japan.

Before going further the authors wish to express their gratitude to Messers N. KÔDA, K. AKITA and Y. IMAGAWA, who gave valuable materials for this study.

MATERIALS

The materials used are shown in the following.

Leptidea amurensis amurensis Ménétriès
Eurema hecabe mandarina de l' Orza
E. laeta bethesba Janson
E. brigitta drona Horsfield
E. blanda arsakia Fruhstorfer
Colias erate poliographus Motshulsky

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C. palaeno aias Fruhstorfer
Gonepteryx rhamni maxima Butler
G. aspasia niphonica Verity
Aporia crataegi adherbal Fruhstorfer
A. hippia japonica Matsumura
Anthocharis scolymus scolymus Butler
A. cardamines issikii Matsumura
Pieris rapae curcivora Boisduval
P. melete melete Ménétriès
P. napi japonica Shirôzu
P. canidia canidia Sparrman
Appias paulina minato Fruhstorfer
A. albina semperi Moore
・*A. lyncida formosana* Wallace
・*A. nero palawanica* Staudinger
・*Leptosia nina georgi* Fruhstorfer
Catopsilia pomona pomona Fabricius
C. pyranthe pyranthe Linnaeus
Hebomoia glaucippe formosana Fruhstorfer
・*Ixias pyrene insignis* Butler

・ : not inhabitant, though sometimes captured in Japan

GENERAL STRUCTURE OF OCCIPITAL REGION (Fig. 1)

The occipital region of Pieridae is composed of 2 main parts, viz. dorsal part of occiput, postocular plate with occipital foramen. A ratio of the width (W) to the height (H) of the occiput (W/H ratio) ranges 1.8–2.3 (Table 2). The coloration of the occiput generally takes black or dark brown.

1. Dorsal part of occiput (Fig. 1, Dpo.)

The dorsal part of occiput consists of 2 parts, such as big occipital prominence and small intermediate plate. The former occupies the central part, and the latter the dorsal sides. Both of them are covered with scales. The dorsal part of occiput develops to some extent laterally. The occipital prominence protrudes to the dorsal and posterior directions strongly in several genera (ex. *Eurema* : Photo 2, *Anthocharis* : Photo 6), and weakly in some others (ex. *Pieris* : Photo 7, *Hebomoia* : Photo 11). Such genera as *Pieris* (ex. Photo 39) and *Appias* (ex. Photo 47) have the sharply projected intermediate plate, but the others (ex. *Gonepteryx* : Photo 27, *Catopsilia* : Photo 59) not. The intermediate plate is

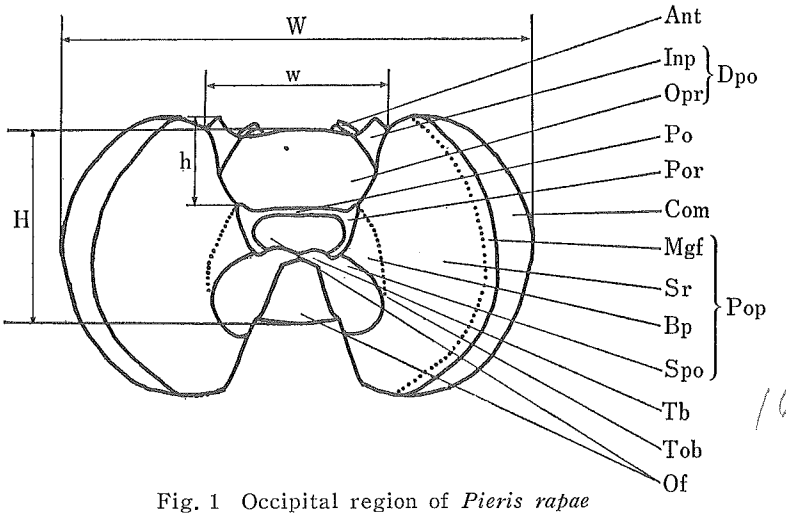


Fig. 1 Occipital region of *Pieris rapae*
Ant-Antenna, Bp-Basal part, Com-Compound eye, Dpo-Dorsal part of occiput, Inp-Intermediate plate, Mgf-Marginal furrow, Of-Occipital foramen, Opr-Occipital prominence, Po-Postocciput, Pop-Postocular plate, Por-Postoccipital ridge, Spo-Side part of occipital foramen, Sr-Scaled region, Tb-Tentorial bridge, Tob-Transoccipital band.

generally shaped like a triangle.

A ratio of the width (w) to the marginal height (h) (w/h ratio) ranges 2.0–3.5 and that of the width (w) to the width of occiput (W) varies 0.39–0.60. (Table 2).

2. Postocular plate (Fig. 1, Pop.)

The postocular plate is divided into 5 parts; e.g. peripheral part of compound eye, marginal furrow, scaled region, basal part and side part of occipital foramen. This plate swells largely.

a) Peripheral part of compound eye

It is generally too narrow to be recognized.

b) Marginal furrow

No scales are grown. In many species boundary region along the peripheral part of compound eye is furnished with densely fine wrinkles, but not in the other part. Small tubercles are scattered in a few species (ex. *Appias nero*: Photo 85). The sensory organ is found in most species.

A ratio of the width(F) to the facetal diameter(d) is 1.8–4.5 (Table 2).

c) Scaled region (Fig. 1, Sr.)

Scales are distributed densely. Besides proximally running fine wrinkles are observed in many species. No small tubercles are grown with exception of some

genera or species (ex. *Appias* : Photo 85, *Leptosia* : Photo 86, *Hebomoia* : Photo 89). The sensory organ is generally located.

d) Basal part and side part of occipital foramen (Fig. 1, Bp., Spo.)

No scales are found. The basal part is smooth and distinguished by the transoccipital band from the scaled region. The side part of occipital foramen is covered with small tubercles and small setae.

3. Occipital foramen (Fig. 1, Of.)

It is separated into the dorsal and ventral parts by the tentorial bridge. The former is wider than the latter. The dorsal margin of the former curves to the dorsal direction. The postocciput develops and its dorsal part protrudes strongly to the posterior direction. The postoccipital ridge develops well except in *Eurema* (Photo 15) and *Leptosia* (Photo 55). The probossidial fossa is deep.

4. Occipital type (Table 2)

The marginal furrow and the scaled region bear generally no small tubercles. The main occipital type of Pieridae belongs to AA-AA.

OCCIPITAL STRUCTURE IN EACH GENUS

The size of the occipital part and the occipital type in each genus and species were shown in Table 1, 2.

1) *Leptidea* (Photo 1, 13, 14, 65)

The occipital prominence is characteristically divided laterally into 2 parts

Table 1. The characters of occipital structure in each genus of Pieridae.

Genus	W/H	w/h	w/W	F/d	Occipital type
Leptidea	2.2	2.6	0.56	1.8	AA-AA
Eurema	1.9	2.1	0.51	2.3	AA-AA
Colias	2.1	2.7	0.55	2.9	AA-AA
Gonepteryx	1.8	3.2	0.58	3.2	AA-AA
Aporia	1.9	2.8	0.48	4.1	AA-AA
Anthocharis	2.1	2.9	0.59	3.0	AA-AA
Pieris	2.1	2.3	0.44	2.8	AA-AA～AA-PP
Appias	2.2	2.1	0.39	2.6	AA-PP～PA-PP
Leptosia	2.3	2.0	0.44	2.1	AA-PP
Catopsilia	2.2	3.1	0.47	3.2	AA-AA
Hebomoia	2.1	2.8	0.47	4.0	AA-PP
Ixias	2.2	2.3	0.47	2.6	AA-AA

Table 2. The characters of occipital structure in each species of Pieridae.

Species	W/H	w/h	w/W	F/d	Occipital type
Leptidea amurensis amurnsis	2.2±0.1	2.6±0.1	0.56±0.07	1.8±0.2	AA-AA
Eurema hecabe mandarina	1.9±0.1	2.1±0.1	0.49±0.02	1.9±0.2	AA-AA
E. laeta bethesba	1.9	2.2	0.55	2.9	AA-AA
E. brigitta drona	2.0	2.0	0.51	2.3	AA-AA
E. blanda arsakia	1.9±0.1	2.0±0.1	0.50±0.02	2.3±0.7	AA-AA
Colias erate poliographus	2.2±0.04	2.5±0.1	0.55±0.02	2.7±0.1	AA-AA
C. palaeno aias	1.9±0.04	2.9±0.1	0.55±0.01	3.1±0.3	AA-AA
Gonepteryx rhamni maxima	1.8±0.1	3.5±0.2	0.60±0.02	3.0±0.8	AA-AA
G. aspasia niphonica	1.8±0.1	2.9±0.1	0.57±0.02	3.3±0.4	AA-AA
Aporia crataegi adherbal	1.9±0.1	2.7±0.2	0.49±0.03	4.5±0.6	AA-AA
A. hippia japonica	2.0±0.1	3.0±0.2	0.48±0.03	3.7±0.6	AA-AA
Anthocharis scolymus scolymus	2.2±0.1	3.1±0.2	0.59±0.01	2.7±0.5	AA-AA
A. cardamines issikii	2.1	2.7	0.58	3.3	AA-AA
Pieris rapae curcivora	2.2±0.1	2.4±0.1	0.46±0.01	2.7±0.3	AA-AP_1
P. melete melete	2.1±0.1	2.3±0.1	0.44±0.01	2.8±0.3	AA-AA
P. rapi japonica	2.1±0.1	2.6±0.2	0.45±0.05	2.6±0.4	AA-AA
P. canidia canidia	2.2±0.1	2.1±0.1	0.42±0.02	2.9±0.3	AA-P_1P_1
Appias paulina minato	2.2±0.1	2.2±0.1	0.40±0.01	2.2±0.2	P_1A-P_1P_1
A. albina semperi	2.2±0.04	2.1±0.2	0.38±0.01	2.6±0.3	AA-P_1P_1
A. lyncida formosanna	2.1±0.1	2.1±0.1	0.39±0.01	2.8±0.8	AA-P_1P_1
A. nero palawanica	2.2±0.1	2.01±0.1	0.39±0.01	2.9±0.1	P_1A-P_1P_1
Leptasia nina georgi	2.3±0.1	2.0±0.2	0.44±0.01	2.1±0.3	AA-P_1P_1
Catopsilia pomona pomoua	2.2±0.04	3.0±0.3	0.45±0.02	3.2±0.3	AA-AA
C. pyranthe pyranthe	2.2±0.01	3.2±0.3	0.50±0.01	3.1±0.4	AA-AA
Hebowoia glaucippe formosana	2.1±0.04	2.8±0.2	0.47±0.02	4.0±0.4	AA-P_1P_1
Ixias pyrene insignis	2.2±0.2	2.3±0.3	0.47±0.03	2.6±0.4	AA-AA

$P<0.05$ (T-test)
In case of under 4 specimens the standerd error is omitted.

(Fig. 2). It protrudes rather strongly to the posterior direction, and also dorsally, though its central part is a little depressed. The dorsal projection of triangular intermediate plate is considerably high. The postocular plate is protruded weakly. Proximally running fine lines cover over the marginal furrow and the scaled region. The marginal furrow is narrowest (F/d=1.8). The occipital type belongs to AA-AA.

2) *Eurema* (Photo 2, 15–22, 66–69)

The occipital prominence is not divided. It protrudes largely to the posterior direction having a special prominence at its dorsal center. The prominence makes a reversed V-shaped line. The triangular intermediate plate also projects rather strongly. The postocular plate is convex very weakly. The postoccipi-

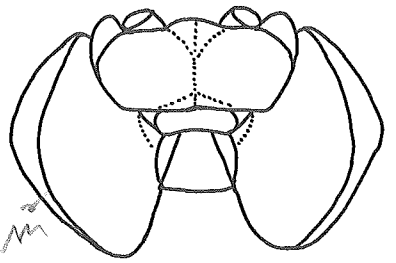


Fig. 2 Occipital region of *Leptidea amurensis*.

tal ridge develops very poorly. The marginal furrow has neither small tubercles nor wrinkles. The scaled region is covered with proximally running fine lines. W/H and w/h ratios (1.9, 2.1) are small. The occipital type is AA-AA.

3) *Colias* (Photo 3, 23–26, 70, 71)

The occipital prominence is protuberent rather strongly to the posterior and dorsal directions. Differing from those of 2 previous genera, the triangular intermediate plate is hardly projected. The postocular plate is protruded rather hard. The postoccipital ridge develops weakly. The structure of marginal furrow and scaled region is similar to that of *Eurema* except that the inner part of scaled region has stout wrinkles running to all dierctions. w/W ratio (5.5) is very large. The occipital type belongs to AA-AA.

4) *Gonepteryx* (Photo 4, 27–30, 72, 73)

The development of occipital prominence is greatest to the dorsal and posterior directions (Fig. 3) in Pieridae. The intermediate plate does not project. The postocular plate has remarkably strong protrusion. The structure of marginal furrow and scaled region is the same as that of *Eurema*. W/H ratio (1.8) is smallest in this family. w/h ratio (3.2) is largest. Besides w/W one (0.58) is very large. The occipital type is AA-AA.

5) *Aporia* (Photo 5, 31–34, 74, 75)

The occipital prominence protrudes rather strongly to the posterior and dorsal directions. The intermediate plate and the postocular plate protrude weakly. In the marginal furrow and scaled region structural characters are similar to that of *Leptidea*. The marginal furrow is widest (F/d= 4.1). The occipital type is AA-AA.

6) *Anthocharis* (Photo 6, 35–38, 76, 77)

The occipital prominence protrudes remarkably to the posterior direction provided with a slightly caved portion in the dorsal part as in Fig. 4. The intermediate plate is shaped like a slender triangle and hardly projecting dorsally. The postocular plate is protuberant rather hard. The structure of marginal furrow and scaled region resembles that of *Eurema* ex-

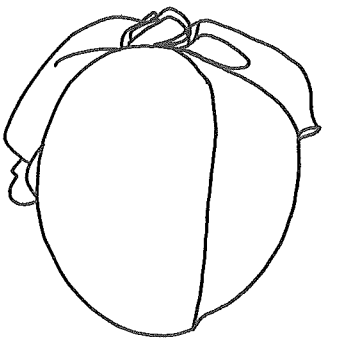


Fig. 3 Lateral view of head in *Gonepteryx rhamni*.

ception in inner part, the outer part of which is covered with big proximally running wrinkles. The sensory organ is absent. w/W ratio (0. 59) is largest. The occipital type belongs to AA-AA.

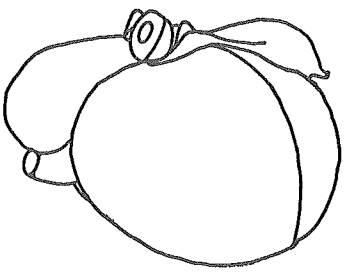


Fig. 4 Lateral view of head in *Anthocharis scolymus*.

7) *Pieris* (Photo 7, 39–46, 78–81)

The occipital prominence protrudes weakly to the posterior and dorsal directions. The intermediate plate, somewhat slender quadrangle shaped, projects markedly to the dorsal direction. In *P. melete* the plate seems longer than in *P. nape*. The postocular plate is weakly protruded. The structure of marginal furrow and scaled region is the same as that of *Eurema*, though in *P.* rapae small tubercles are scattered in the inner part of the latter. In *P. canidia* small tubercles are found in the scaled region and many fine wrinkles running to all directions in its inner part. The occipital type of *P. napi* and *P. melete* belong to AA-AA. Those of *P. canidia* and *P. rapae* are AA-P_1P_1 and AA-AP_1, respectively.

8) *Appias* (Photo 8, 47–54, 82–85)

The structure of the occipital region is similar to that of *Pieris* except in the followings.

1. The occipital prominence and postocular plate protrude more weakly than those of *Pieris*.
2. The occipipital type is P_1A-P_1P_1 in *A. paulina* and *A. nero*, though AA-P_1P_1 in *A. albina* and *A. lyncida*.
3. w/W ratio (0. 39) is smaller.

The scaled region has small tubercles. Only in *A. paulina* and *A. nero* the outer part of marginal furrow has also them. Moreover dorso-ventral wrinkles and fine wrinkles running to all directions are seen in *A. alblna* and in the others, respectively in the inner part of scaled region.

9. *Leptosia* (Photo 9, 55, 56, 86)

The structure of occipital region resembles that of *Pieris*, but the followings are different.

1. The projection of intermediate plate is rather weaker.
2. The shape of intermediate plate makes a triangle.
3. The postocular plate is smaller.
4. The inner part of marginal furrow is covered with proximally running fine wrinkles.

5. W/H ratio (2.3) is larger while w/h one (2.0) is smaller.

The occipital type belongs to AA-P_1P_1.

10) *Catopsilia* (Photo 10, 57–60, 87, 88)

The occipital structure resembles that of *Appias*, but is distinguishable by the following points.

1. The intermediate plate projects very slightly to the dorsal direction.
2. The intermediate plate makes a triangle.
3. The inner part of scaled region is provided with dorso-ventral big wrinkles.
4. The occipital type belongs to AA-AA.

11) *Hebomoia* (Photo 11, 61, 62, 89)

The structure of occipital region is similar to that of the *Catopsilia* with the exception of the followings.

1. The intermediate plate is melanized more weakly, especially in the top.
2. The intermediate plate protrudes more sharply.
3. The occipital type is AA-P_1P_1.

12) *Ixias* (Photo 12, 63, 64, 90)

The occipital prominence protrudes weakly to the posterior and dorsal directions. Besides the intermediate plate and the postocular plate are slightly protuberent. The outer part of marginal furrow and the central part of scaled region are provided with proximally running fine lines. Furthermore inner part of the latter bears big lines while the rest is smooth. The occipital type is AA-AA.

GROUPING OF PIERIDAE BASED ON THE OCCIPITAL STRUCTURE

In Pieridae the occipital structure varies according to genus or species as mentioned above. *Leptidea*, however, is independently different from the other genera in having divided occipital prominence. This must be a diagnostic indicator in the occipital structure (Group A).

The others, with the undivided occipital prominence (Group B), are separable into 2 main groups and 4 subgroups based on the grade of protruded occipital prominence and the height of intermediate plate.

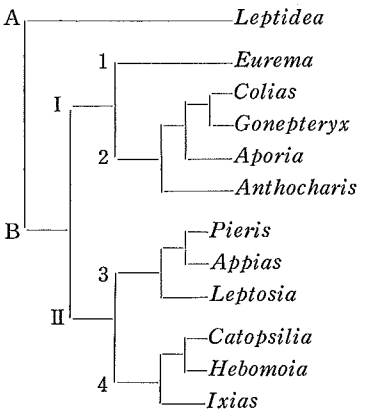
Group I. The occipital prominence protrudes greatly to the posterior direction. *Eurema*, *Colias*, *Gonepteryx*, *Aporia* and *Anthocharis* belong to this group. The occipital type is uniformly AA-AA.

Subgroup 1. The intermediate plate projects highly to the dorsal direction. This subgroup contains *Eurema*.

Subgroup 2. The intermediate plate projects weakly to the dorsal directions. *Colias*, *Gonepteryx*, *Aporia* and *Anthocharis* belong to this subgroup. *Anthocharis*

is distinguished from the others in the slender intermediate plate and in the occipital prominence with depressed dorsal part. Then *Aporia* differs from the others in w/W and F/d ratios. Besides *Colias* is discriminated from *Gonepteryx* in w/W ratio (*Col.* 0.55, *Gon.* 0.58) and the grade of posterior protrusion in the occipital prominence.

Fig. 5 Grouping of Pieridae based on the occipital structure.



Group II. The occipital prominence protrudes weakly to the posterior direction. This group includes *Pieris*, *Appias*, *Catopsilia*, *Hebomoia*, *Leptosia* and *Ixias*. The occipital type varies from AA-AA to PA-PP.

Subgroup 3. The intermedeate plate projects sharply to the dorsal direction. This subgroup contains *Pieris*, *Appias*, and *Leptosia*. *Leptosia* is separated from the others by the slender shape of intermediate plate. *Pieris* and *Appias* are very similar to each other, though w/W ratio is different (*Pie.* 0.44, *App.* 0.39). The occipital type is not uniform though small tubercles are grown in many species.

Subgroup 4. The intermediate plate projects faintly to the dorsal direction. *Catopsilia*, *Hebomoia* and *Ixias* belong to this subgroup. *Catopsilia* and *Hebomoia* are separable from *Ixias* by the extremely poorly protruded occipital prominence. Moreover *Catopsilia* is distinguished from *Hebomoia* by F/d ratio (*Cat.* 3.2, *Heb.* 4.0) and dorsal coloration of intermediate plate. The occipital type varies from AA-AA to AA-PP.

The grouping of Pieridae based on the occipital structure is shown as in Fig. 5.

COMPARISON OF PIERIDAE WITH NYMPHALIDAE, LIBYTHEIDAE AND PAPILIONIDAE IN THE OCCIPITAL STRUCTURE

The occipital region of Pieridae comprises the dorsal part of occiput, the postocular plate and the occipital foramen as seen in Nymphalidae, Libytheidae and Papilionidae (TSUBUKI and KOYAMA, 1978). The range of W/H ratio in Pieridae is the same as that in Papilionidae, which is shown in Table 3.

The dorsal part of occiput in Pieridae intrudes into the postocular plate, though not so strongly as that in Papilionidae. In the structure of the dorsal

Table 3. The characters of occipital structure in 4 families.

	W/H	w/h	w/W	F/d
Pieridae	1.8～2.3	2.0～3.5	0.38～0.60	1.8～4.5
Papilionidae	1.8～2.3	1.7～2.9	0.43～0.85	1.4～3.4
Nymphalidae	1.7～2.6	1.5～3.3	0.29～0.53	2.0～6.3
Libytheidae	2.5	2.9	0.40	2.3

part of occiput, Pieridae is characterized by w/h ratio indicating the part is laterally long. It is much bigger than that in the other 3 families (Table 3). Besides the occipital prominence is very large and the intermediate plate very small situated laterally. w/W ratio is ordered Papilionidae > Pieridae > Nymphalidae and Libytheidae (Table 3). The connection part is absent as in Paplionidae.

In the postocular plate Pieridae is samely composed of 5 parts as the other 3 families, and the peripheral part of compound eye develops very poorly. The occipital type is generally AA-AA as in Papilionidae.

In the occipital foramen, the ventral one is narrower and higher than that in the other families. The probosidial fossa is also deeper.

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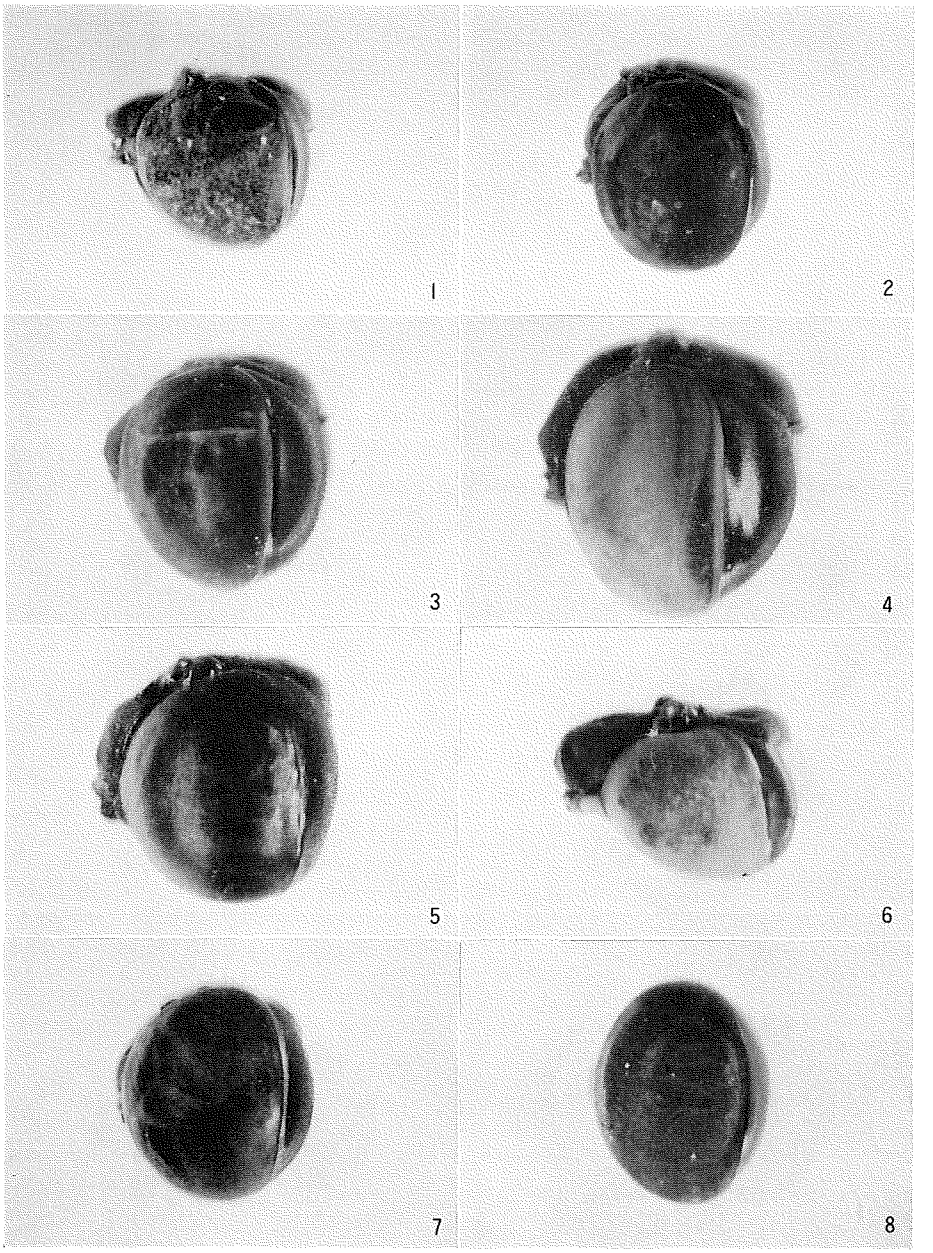
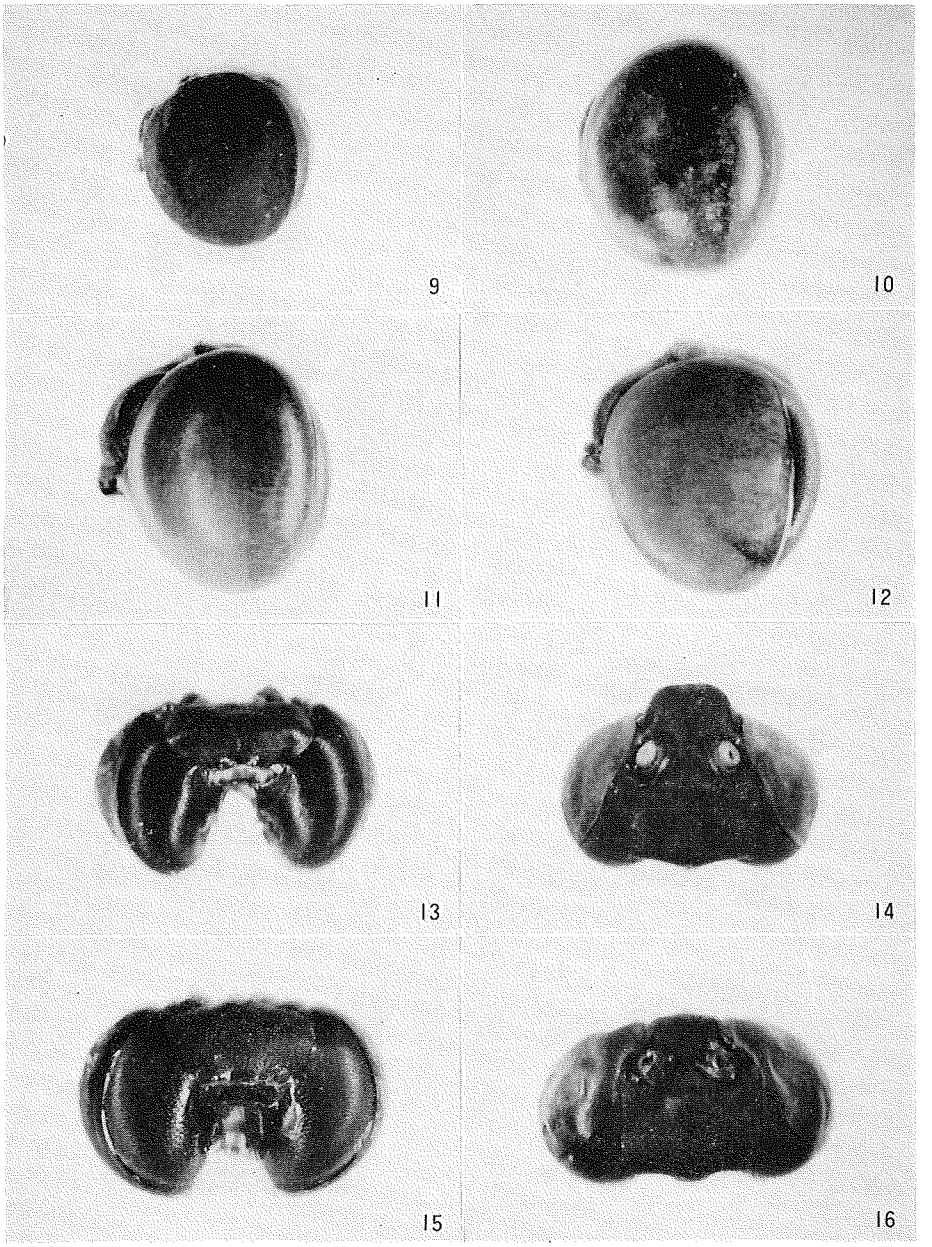
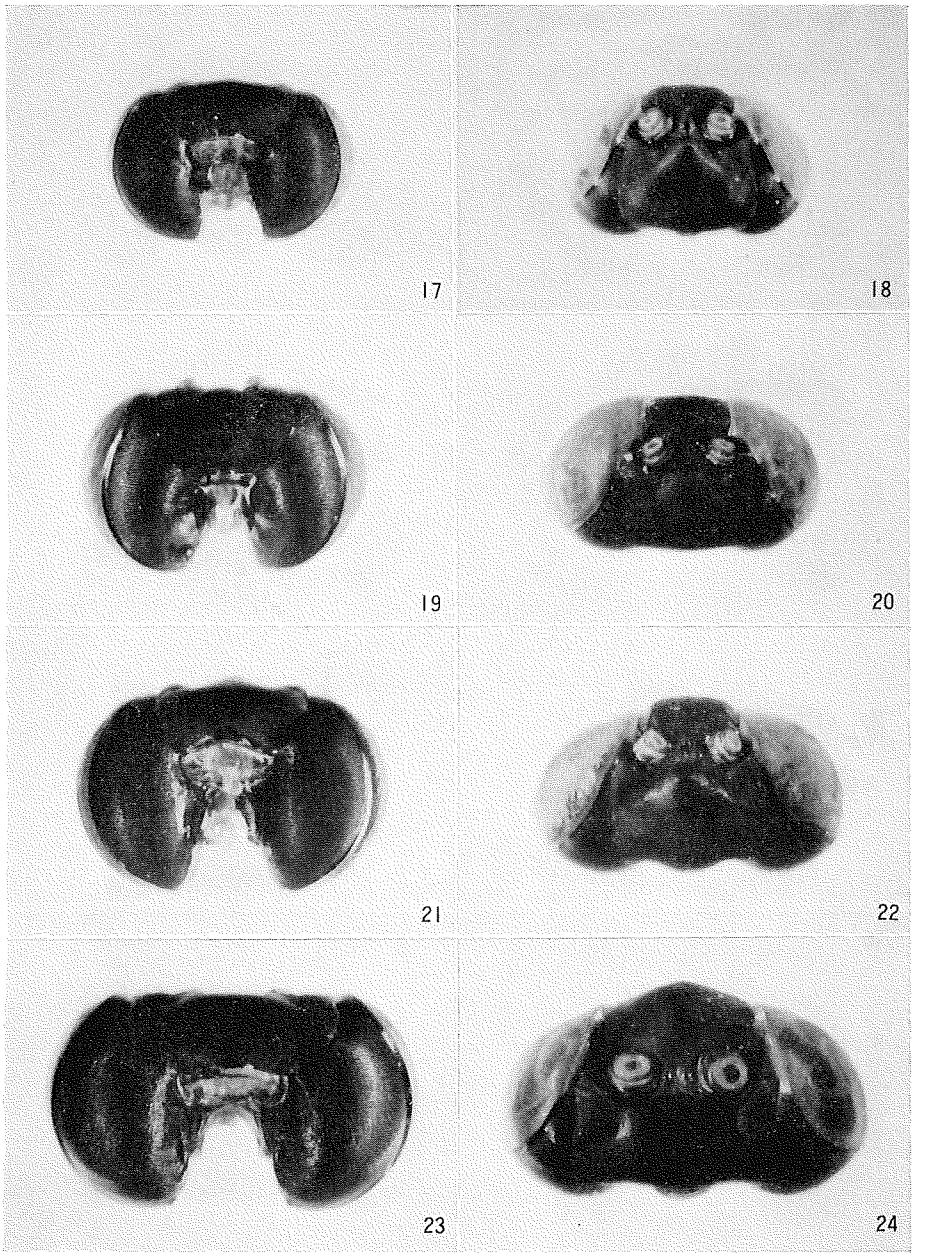


I Photo 1–12. Lateral view of head (×17, except for 8, 10.)

1. *Leptidea amurensis*
2. *Eurema hecabe*
3. *Colias erate*
4. *Gonepteryx rhamni*
5. *Aporia crataegi*
6. *Anthocharis scolymus*
7. *Pieris rapae*
8. *Appias paulina* (×14)

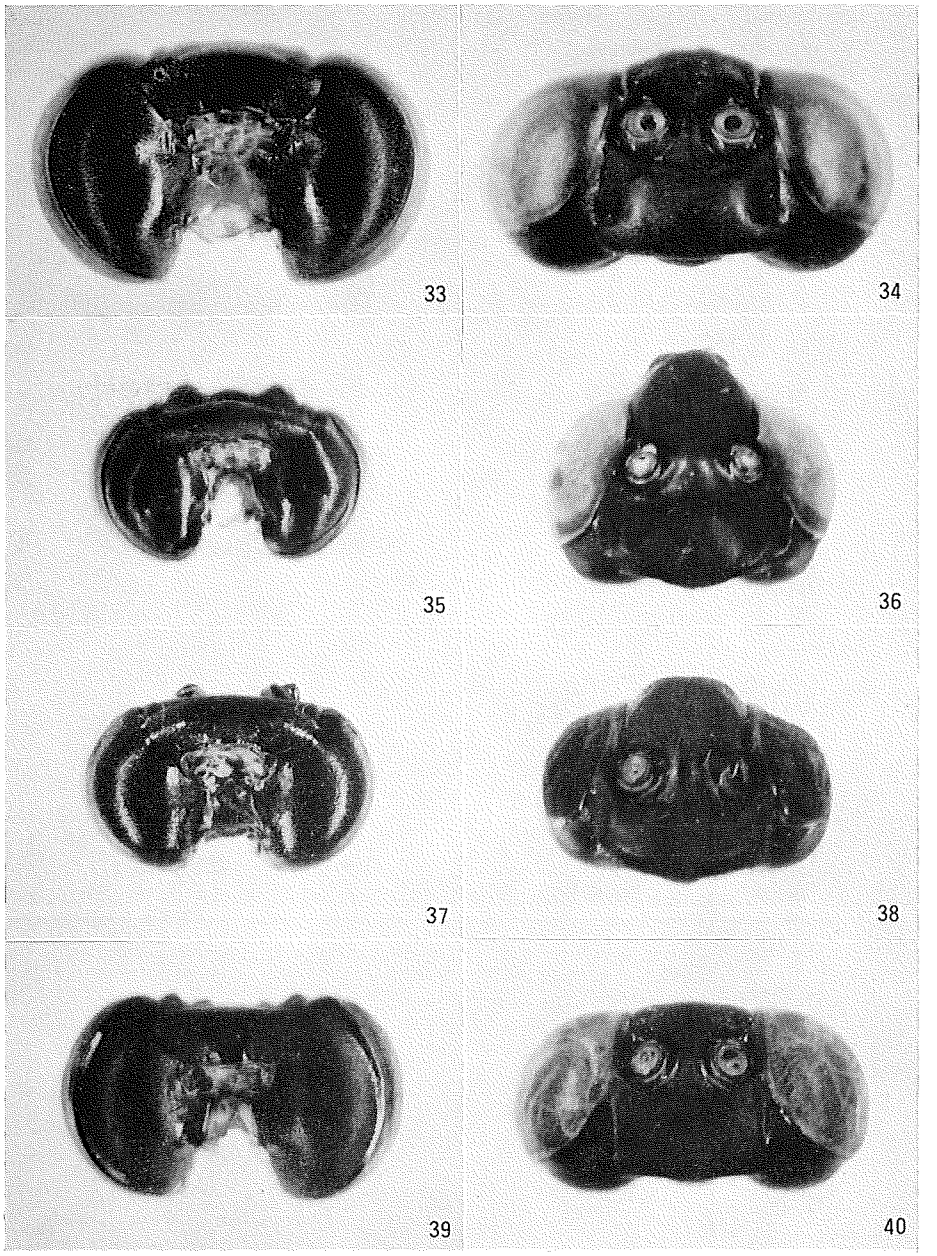


II 9. *Leptosia nina* 10. *Catopsilia pomona* (×14)
11. *Hebomoia glaucippe* (×11) 12. *Ixias pyrene*
Photo 13–64. Posterior view(left) and dorsal view(right) of head (×17) except for 47～54, 57～62)
13, 14. *Leptidea amurensis* 15, 16. *Eurema hecabe*

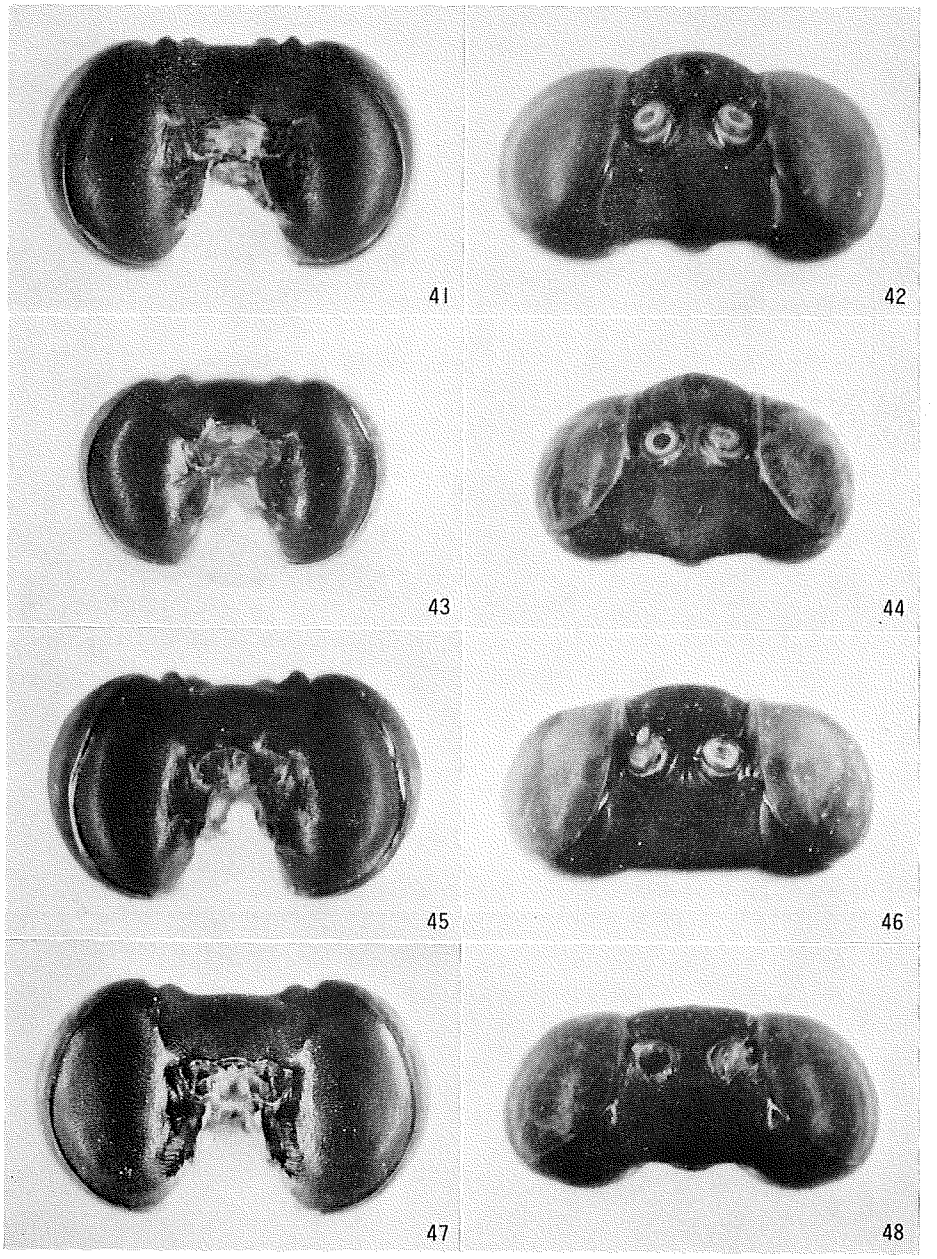


III 17, 18. *Eurema laeta* 19, 20. *E. brigitta*
21, 22. *E. blanda* 23, 24. *Colias erate*

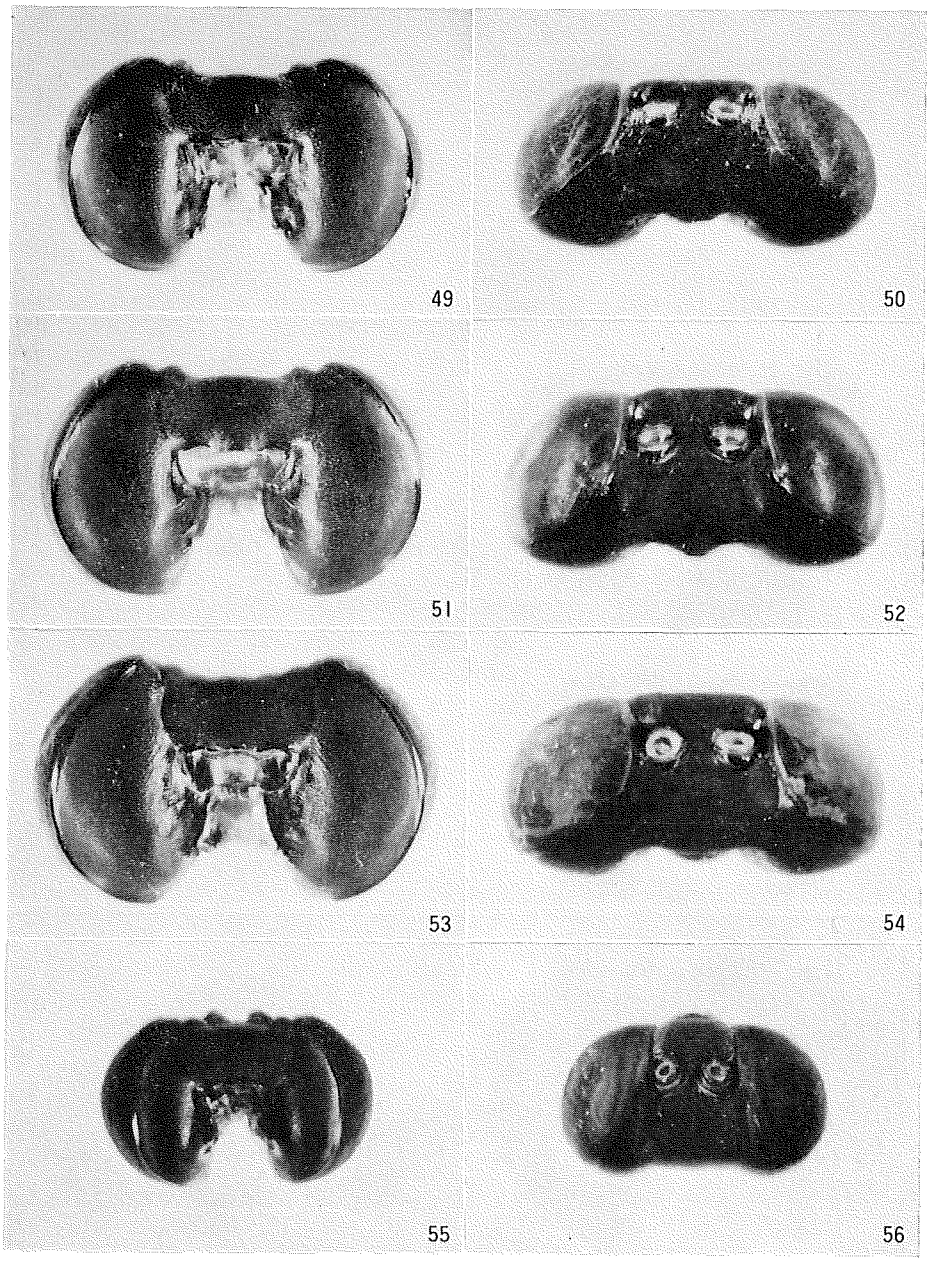
IV 25, 26. *Colias palaeno* 27, 28. *Gonepteryx rhamni*
29, 30. *G. aspasia* 31, 32. *Aporia crataegi*



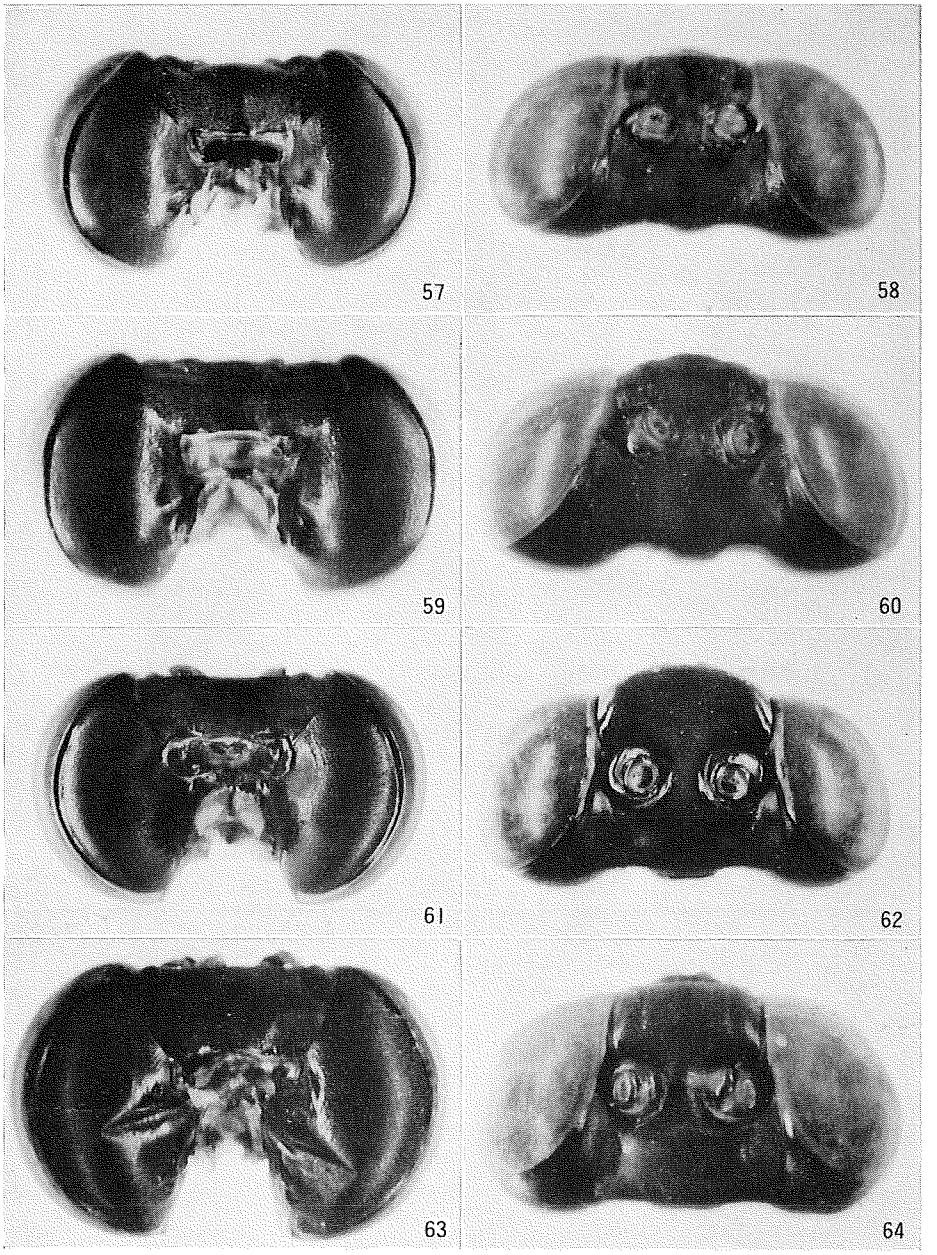
V 33, 34. *Aporia hippia* 35, 36. *Anthocharis scolymus*
37, 38. *A. cardamines* 39, 40. *Pieris rapae*



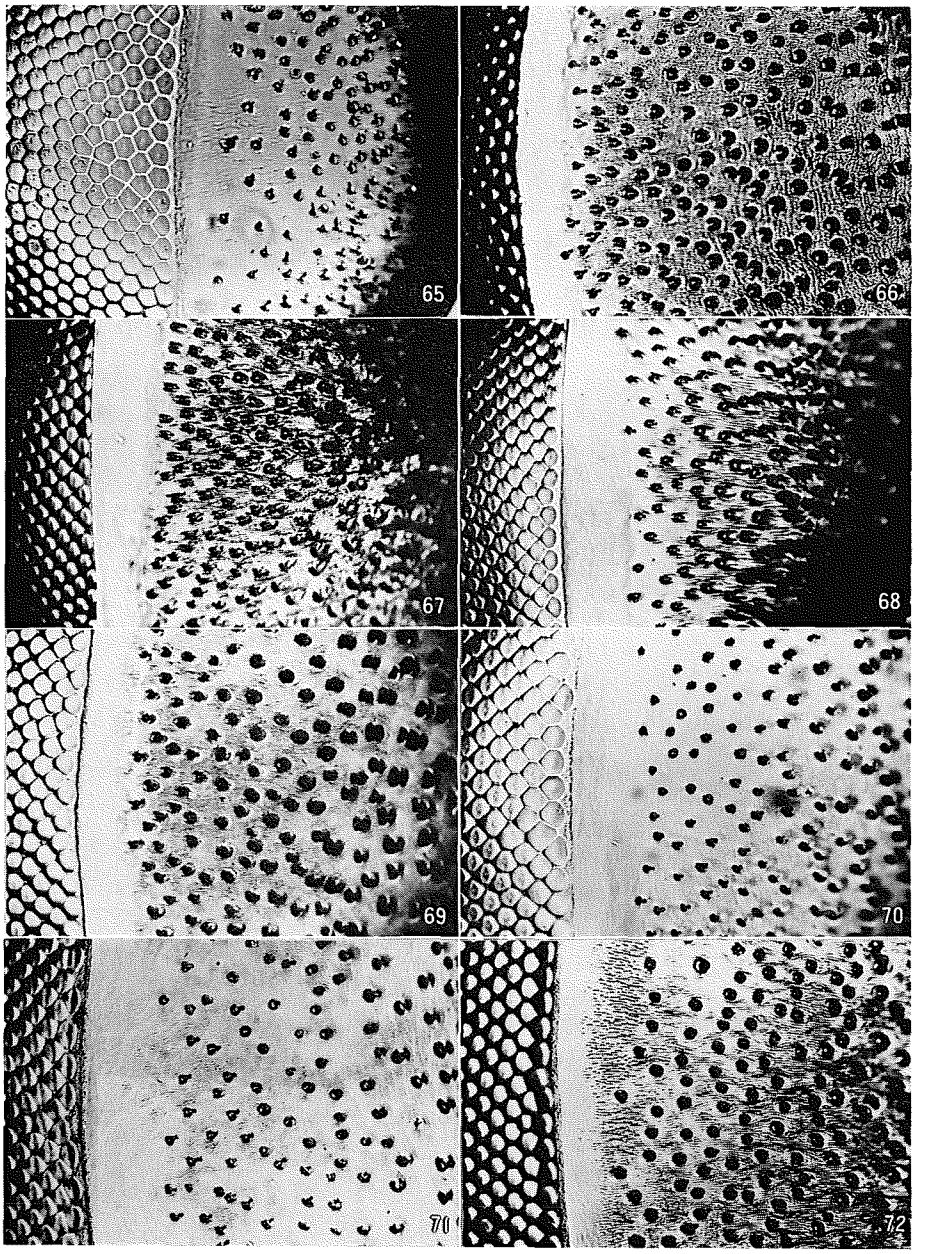
VI 41, 42. *Pieris melete* 43, 44. *P. napi*
45, 46. *P. canidia* 47, 48. *Appias paulina* (×14)



Ⅶ 49, 50. *Appias albina* (×14) 51, 52. *A. lyncida* (×14)
53, 54. *A. nero* (×14) 55, 56. *Leptosia nina*

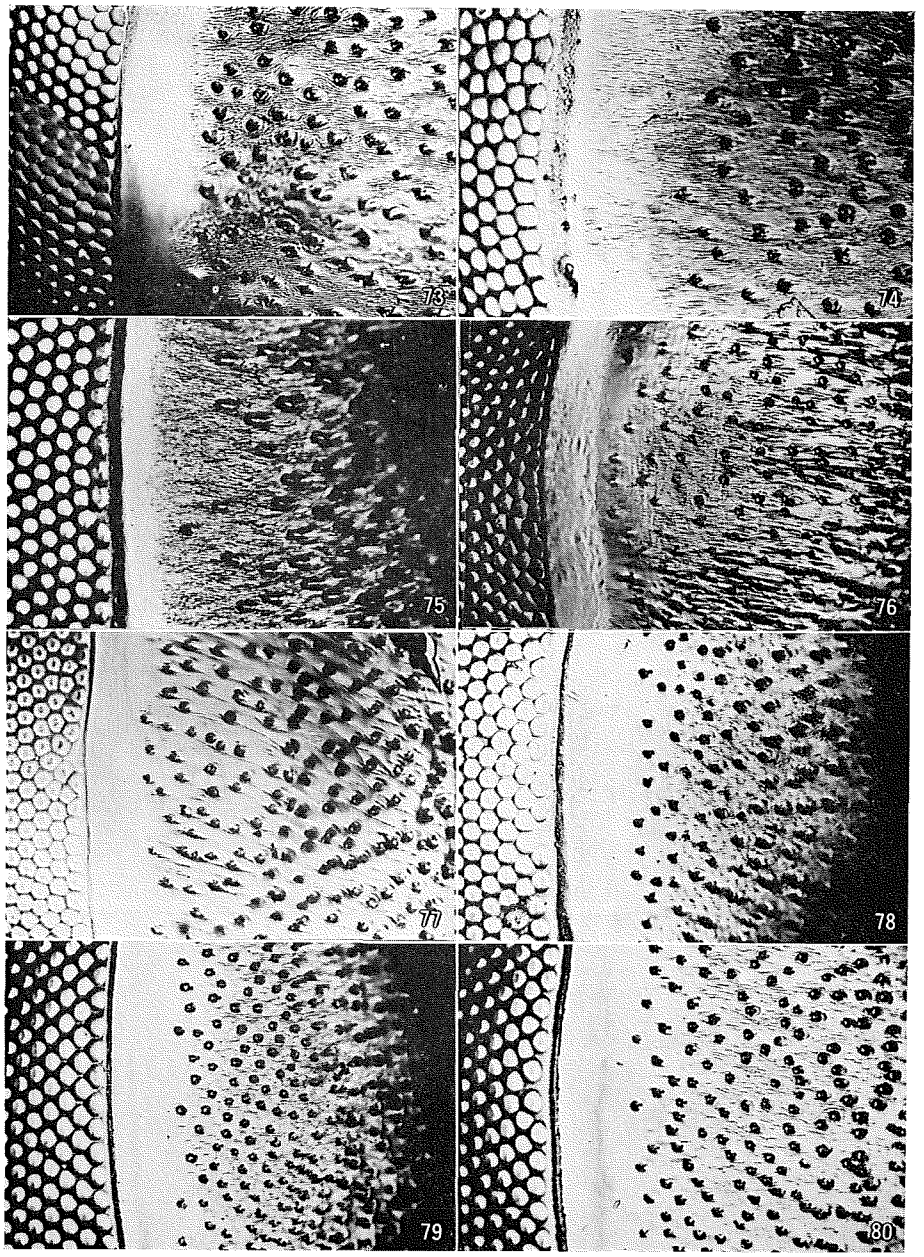


VIII 57, 58. *Catopsilia pomona* (×14) 59, 60. *C. pyranthe* (×14)
61, 62. *Hebomoia glaucippe* (×11) 63, 64. *Ixias pyrene*

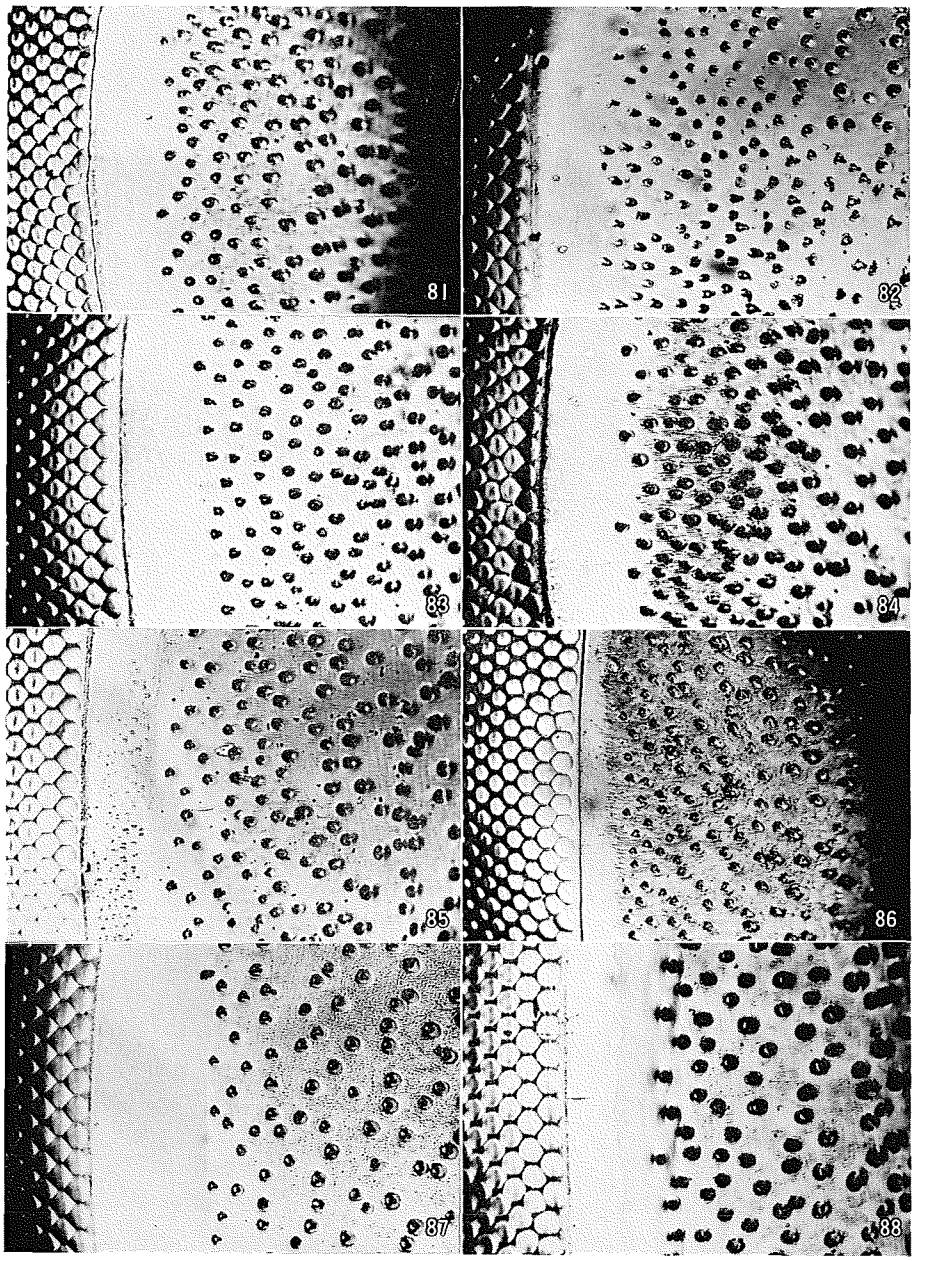


IX Photo 65–90. Occipital structure (×250)

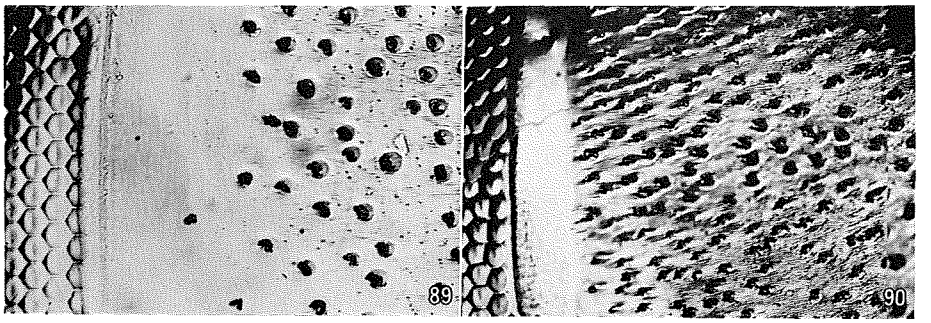
65. *Leptidea amurensis*
66. *Eurema hecabe*
67. *E. laeta*
68. *E. brigitta*
69. *E. blanda*
70. *Colias erate*
71. *C. palaeno*
72. *Gonepteryx rhamni*



X 73. *Gonepteryx aspasia*
74. *Aporia crataegi*
75. *A. hippia*
76. *Anthocharis scolymus*
77. *A. cardamines*
78. *Pieris rapae*
79. *P. melete*
80. *P. napi*



XI 81. *Pieris canidia*
82. *Appias paulina*
83. *A. albina*
84. *A. lyncida*
85. *A. nero*
86. *Leptosia nina*
87. *Catopsilia pomona*
88. *C. pyranthe*



XII 89. *Hebomoia glaucippe* 90. *Ixias pyrene*