STUDIES ON THE COMPOUND EYES OF LEPIDOPTERA

3. On the Pseudopupil of Gonepteryx Butterflies *・**

by

Nobumasa YAGI and Nagao KOYAMA

(*manuscript recieved Dec. 10, 1955*)

INTRODUCTION

Among the pseudopupils found in *Pierid* butterflies the form of pupillar patterns of two species in the genus *Gonepteryx* are changeable according to the environmental condition of luminescens. This colour change is caused by the pigment migration in the primary and accessory pigment cells.

This article deals with the result of our research on the pigment movement in the compound eyes of *G. rhamni maxima* BUTLER and *G. mahaguru niphonica* VERITY.

MATERIAL AND METHOD

The outer change of the pattern of the pseudopupil was observed day time (at 1 p.m.) on the butterfly kept in the natural condition and night (at 8 p.m.) in the dark room (25°C).

Internal morphology was observed on the eye fixed with Carnoy's solution and sectioned with paraffin in 10μ thickness stained with Heidenhein's haematoxylin or without stain.

MORPHOLOGY OF THE COMPOUND EYE

The colour of the compound eye of *G. rhamni* and *G. mahaguru* is yellowish green ornamented with a central pupil and six side pupils, the former has no central light colour spot and the latters are smaller than the former in size, both being surrounded by the dark irregular patterns (pl. I, 3) which had not been found in the eyes of the other species in *Pieridae* (YAGI, 1951). The shape of these interspacial patterns are different individually in the two species of *Gonepteryx* and the dark area in the eye of *G. rhamni* is more conspicuous than that of *G. mahaguru*. The area of these pattern grows broader in the light condition (Pl. I, 3L) and becomes narrower in the darkness (Pl. I, 3D). The area of the pseudopupil changes correspondent to the above phenomenon, but less conspicuous than the change of the former pattern.

INTERNAL STRUCTURE

The whole structure of the compound eye of *Gonepteryx* (Pl. I, 1) is very near to that of *Pieris napi* observed by DEMOLL (1909). The actual observations on the *Gonepteryx* eye are described as follows.

---

*Contribution No. 27 from the Laboratory of Biology and Entomology, the Faculty of Textile and Sericulture, Shinshu University, Ueda, Japan.

**This study was aided by the scientific Research Expenditure of the Educational Department, to which the authors express their hearty thanks.

Cornea (Pl. I, a)

The corneal lens is transparent and concavo-convex having three layers. The first layer is 2μ in thickness, the second one 12μ and the third one 16μ. The second and the third layers are lined wavy and the former layer is constricted to form the boundary between the adjacent facet. The diameter of the cornea is 23.5μ.

Corneal process (Pl. I, b) **and Semper's cell** (Pl. I, II, c)

Corneal process shows an elongated countersunk-head shape lying underside to the cornea on the upper position of the Semper's cell which is composed of four flatt cells with a roundish nucleus in each.

Crystalline cone (Pl. I, d)

Crystalline cone has a bullet shape being composed of four cells as a usual crystalline cone measuring 11.6μ in diameter and 23–25μ in length. The body of the crystalline cone is enveloped by the transparent crystalline sheath. By staining with Heidenhein's haematoxylin the complex pattern appears on its surface (Pl. I, 1d) as it has been observed in the eye of *P. napi* (NOWIKOFF, 1931). This staining tendency suggests the complexity of the surface of the cone.

Main pigment cell (Pl. I, II, e)

The pigment cell called iris or primary pigment cell encircles the crystalline cone by two in number penetrating their each distal end into the engraved part of the corneal process. The cell contains a nucleus and brilliant yellowish granules which had been called as an iristapetum (GRENACHER, 1879). The existence of this pigment is not limited in the *Gonepteryx* eye but seen in the compound eyes of the other species of *Pieridae*, of mantis (HESSE, 1908; ZIMMERMANN, 1914; AINO, 1935)and of grasshopper (UCHIDA, H., 1934). It is different from the irridescent pigment in the eye of the beetle, *Copris ochus* (YAGI, 1952, 1954), in which the eye is provided with the pigment granules of guanophore known as „weisses Pigmente" (LEIDIG, 1868) in the eyes of *Palaemonetes* (Crustacea). The migration of this pigment granules occurs downwards when the eye exposed to the light (Pl. I, 4L : Pl. II, 1). In the nocturnal condition the pigment moves upwards very near to the corneal process, so the proximal end of the cell becomes slender (Pl. I, 4D : Pl. II, 2).

Accessory pigment cell (Pl. I, II, f)

The so-called six secondary pigment cells connect with the corneal process which being grooved to receive the fine thread of the former. The cell contains purplish pigment granules even in the finely shriveled portion of the distal part exhibiting the peculiarity of the genus *Gonepteryx*. This pigment cell is provided with a large spherical nucleus (diameter 7.5—8.0μ) which is detectable without stain at the region of 28—30μ distance from the lower end of the cone (Pl. II, 3).

Retinular pigment cell (Pl. I, II, g)

The triangular long cell (275—290μ) extends from the lower part of the cone to the basement membrane in six numbers. Each cell encircles the rhabdom tightly being supplied with purplish granules and a large kidney shaped nucleus (12μ) in its upper center. Two of these cells unite together at the region from the central to the proximal part showing round feature in cross section (Pl. I, 2F : Pl. II, 7).

Basal pigment cell (Pl. I, II, i)

The proximal end of the retinular pigment cell penetrates into the basement membrane with a unit of six cells in an ommatidium. The pigment granules of this cell do not move according to the dark and light environments differing from the eye of *Vanessa urticae* (DEMOLL, 1909) and that of moths (KOYAMA, 1954, 1955). A few branches of trachea penetrate into the part between these pigment cells.

Rhabdom (Pl. I, II, h)

So-called part of rhabdom is enveloped by the retinular pigment cells which unite each other by crossing the central axis of the ommatidium. The spape of cross section of the rhabdom varies partially from the distal end to the proximal part showing roundish at the upper part and crossed shape near above the central part (Pl. II, 8). The affinity to the staining substance of the rhabdom is conspicuous at the center and increases gradually its degree toward proximally. The nucleus of rhabdom situates nearly at the basement membrane. The proportional rates of length of ommatidial component in the compound eyes of two *Gonepteryx* species are shown in Table 1 in comparison with *Bombycidae*.

Table 1

Species	Cornea	Corneal process	Crystalline cone	Retinular part
Gonepteryx	8.8%	3.4%	6.8 %	81 %
Bombycidae	4—6	—	16—24	70—80

THE CAUSE OF THE CHANGE OF THE SHAPE OF PSEUDOPUPIL BY LIGHT AND DARKNESS

As pointed out previously the interstitial pattern which is caused by the pigments in the accessory pigment cells attached to the crevisces of the corneal process, does not change its feature by the migration of pigment granules in the light condition. The superficial change of this part is caused by the movement of the iris pigment cell which retracts downwards by light and returns upwards by darkness, accordingly in the former case the accessory pigment cell is uncovered and seen more clearly through the corneal part than in the latter case. Then, as a whole the colour change of pseudopupillar patterns of the compound eye of *Gonepteryx* is caused indirectly by the movement of the iris cell (matrix cell) contradictorily to the moth eye (YAGI, 1951; KOYAMA, 1954, 1955), in which the up and downward movement of the granules in the retinular pigment cell is concerned.

LITERATURES CITED

AINO, Y. : Oyodobutsu, 7 (1), 1-16 (1935)

DEMOLL, R. : Arch. ges. Physiol., 129, 461-475 (1909)

GRENACHER, H. : Untersuchungen über das Sehorgan der Arthropoden, insbesondere der

Spinnen, Insekten und Crustaceen, 1–188, Göttingen (1879)
HESSE, R. : Das Sehen der niederen Tiere, Jena, Fischer (1908)
KOYAMA, N. : J. Shinshu Univ., 4, 15–62 (1954)
—— Ibid., 5, 19–73 (1955)
LEYDIG, F. : Cited from AINO, Y. (1935)
UCHIDA, H. : Jour. Fac. Sci. Imp. Univ. Tokyo, 3, 517–525 (1934)
YAGI, N. : J. Shinshu Univ., 1, 131–173 (1951)
—— J. New Ent., 2 (1.2), 8–11 (1952)
—— Jap. J. Zool., 11 (2), 223–226 (1954)
ZIMMERMANN, K. : Zool. Jahrb. Anat. Ont., 37, 1–36 (1914)

Abbreviations in figures and photos

a. Corneal lens
b. Corneal process
c. Semper's cell
d. Crystalline cone
e. Main pigment cell
f. Accessory pigment cell
g. Retinular pigment cell
h. Rhabdom
i. Basal pigment cell
j. Basement membrane

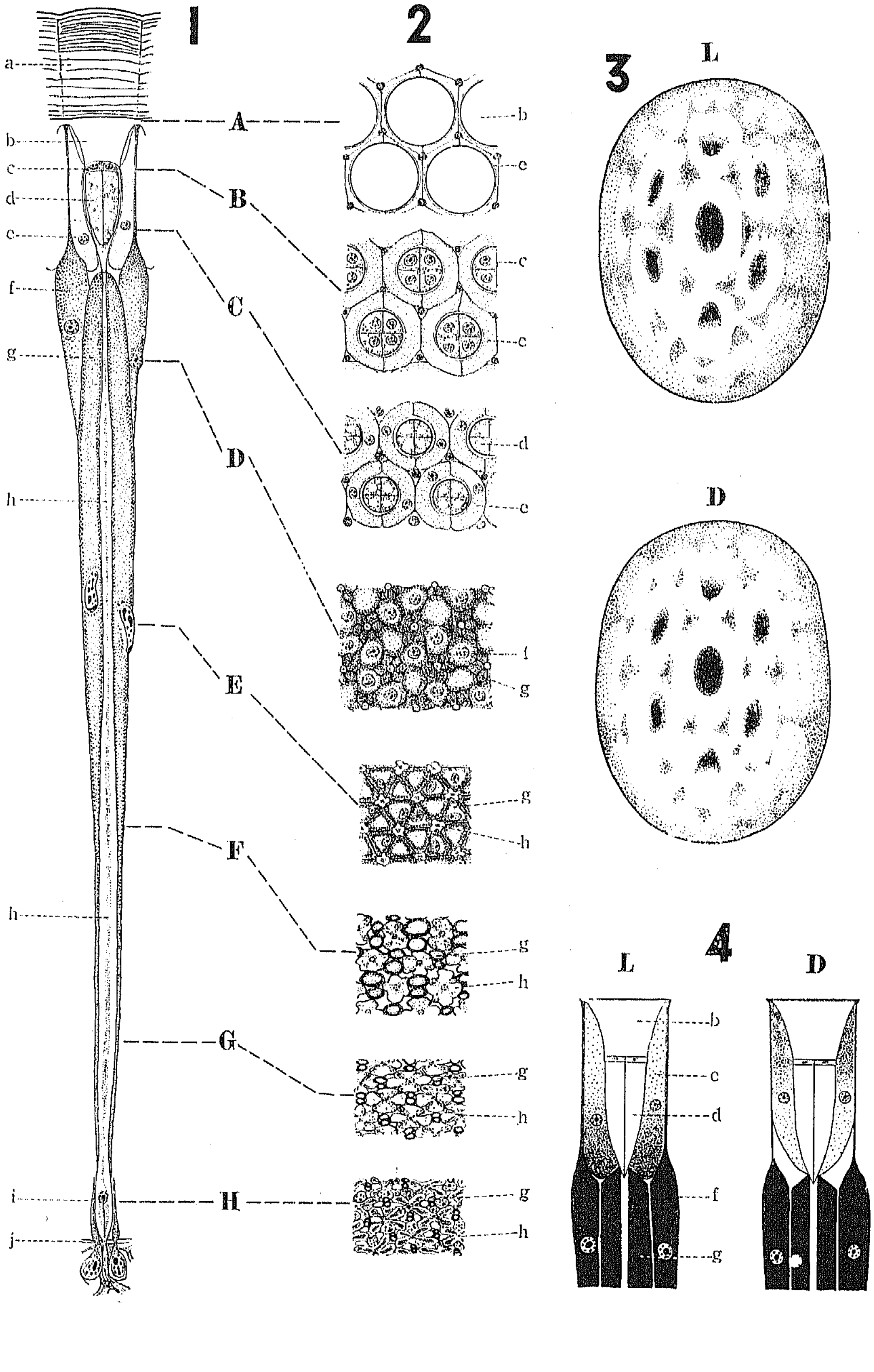
Explanation of plates

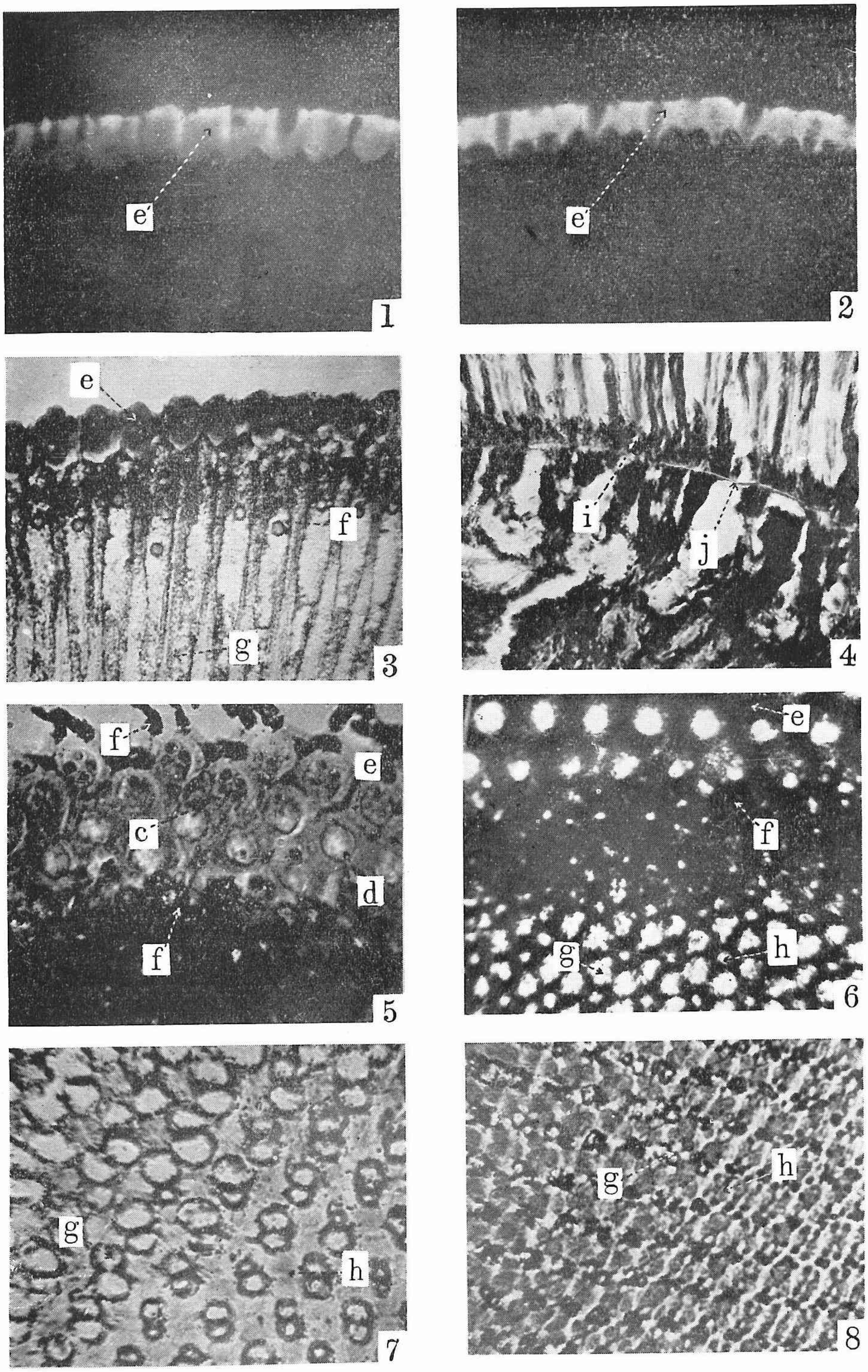
Plate I

1. Longitudinal section of the ommatidium.
2. Cross section of the ommatidium.
3. External appearance (pseudopupil) of the compound eye in light (L) and in darkness (D).
4. Diagrammatic figure of the crystalline parts in light adapted eye (L) and in dark adapted one (D).

Plate II

1. Light adapted state of the main pigment cell (in dark field).
2. Dark adapted state of the above cell (in dark field).
3. Longitudinal section of the distal part of the compound eye.
4. Ditto of the proximal part.
5. Cross section of the distal part of the compound eye.
6. Ditto of the crystalline part.
7. Ditto of the middle part of the retinal layer.
8. Ditto of the lower part of the rhabdom.


1
2
3
4
L
D
A
B
C
D
E
F
G
H
a
b
c
d
e
f
g
h
i
j


e
1
e
2
e
f
g
3
i
j
4
f
e
c
d
f
5
e
f
g
h
6
g
h
7
g
h
8