A Preliminary Note on the Compound Eyes of *Bombycid* and *Saturnian* Moths *

By

Nagao KOYAMA

Many investigations have been done on the compound eyes of *Heterocera* (*Lepidoptera*), but on those of *Bombycid* and *Saturnian* moths we can scarcely find a fundamental study excepting simple descriptions on *Bombyx mori* by TOYAMA & ISHIWATA (1899), IKEDA (1913) and TANAKA (1943).

As stated by YAGI (1951), sense organs including the compound eyes and mouth parts which accept environmental factors will undoubtedly be anticipative organs in the insect evolutions. The investigation of the compound eyes of "Domesticated" insect in comparison with those of "Wild" one must give some important suggestions to the physiology of the development of the vision of insects.

This article is a preliminary note on the study and the detailed descriptions will be published in the succeeding report.

Here the author takes this opportunity of thanking Professor Dr. N. YAGI for his very helpful suggestions and criticisms in regard to the study.

I. EXTERNAL MORPHOLOGY

1. The Form and Colouration of the Compound Eyes

Bombycidae: The compound eyes are seen almost ovoid shapes from the lateral aspect. They show crescent-shapes from the front. Observing dorsoventrally, their surfaces curve steeply towards posterior.

The colour of the compound eyes is generally purplish black, but in some varieties of *Bombyx mori* they are purplish red, orange yellow, white, etc.

Saturniidae: The outer aspect of the compound eyes is similar to those of *Bombycidae*, but a little dorsoventrally elongate and of more egg-like shape than the former.

The colour of the compound eyes is blakcish brown.

2. The Surface Area of the Compound Eyes

The apparent size of the compound eyes generally correlates with that of moths and also with the surface area of the compound eyes. But the surface area of the male is wider than that of the female in the same species (Table 1).

It is an ecologically interesting fact that the compound eyes of the male moth more utilize the light than the female one.

3. The Size of a Corneal Lens

The surface of a facet shows a regular hexagon, a side of which, measuring with a

* Contribution No. 9. from the Biological Laboratory, Faculty of Textile and Sericulture, Shinshu University,

microscope, has 14.0 μ in length in the case of *Bombyx*, 13.0 μ in the case of *Theophila* and 14.5 μ in the case of *Saturniidae*.

The area of a facet is computed as follows:

Bombyx mori	$415\mu^2$
Theophila mandarina	$358\mu^2$
Antheraea pernyi	$446\mu^2$

There is no difference in the size of ommatidia between the male and the female.

4. The Number of Ommatidia

It was reported by TANAKA (1943) that each compound eye of the *Bombyx* moth consists of about 3,000 ommatidia, but these are far lesser than the author's computations (Table 1). Numbers of ommatidia were calculated in order to devide the surface area of compound eyes by the size of ommatidia.

The compound eyes of the male are composed of more numerous facets than those of the female.

Table 1. The number of ommatidia and surface areas of compound eyes (approximate value)

Species	Surface area (μ^2)		Number of ommatidia	
	male	female	male	female
Bombyx mori	2,270,000	2,000,000	5,500	4,800
Theophila mandarina	1,630,000	1,220,000	4,600	3,400
Antheraea pernyi	7,200,000	6,700,000	16,100	15,000

II. INTERNAL MORPHOLOGY

1. The Cornea

The cornea is a concavoconvex lens; the curvature of the inner surface is lesser than that of the outer one.

Three chitinous layers are seen in each corneal lens which is supposed to be correlated to the general layers of cuticle, namely, epicuticle, exocuticle, and endocuticle. The clear real inverted image is formed at some distance from the interior surface of the lens.

The focal length will be computed by application of the general lens formula. But the author measured the focal distance by the direct method using a microscope as DETHIER did.

The images of a human hand formed at the inner part of the cornea are shown in Photo I.

The focal lengths of corneal lenses are shown in the following table.

Table 2. Focal length of the corneal lenses

Species	The length (μ)
Bombyx mori	68
Theophila mandarina	49
Antheraea pernyi	44

In the *Bombyx* moth the ranges of image formation of one cornea are shown in Table 3. Through the corneal lens the 10 cm substance at the distance of 34 cm from the lens is seen 16 μ in length and the same substance at the distance of 77 cm is reduced to 7 μ in length.

Table 3. The range of image formation of a corneal lens.

Distance from substance to cornea (cm)	Number of ommatidia forming images in the same time	
	longitudinal	lateral
23	13	26
30	12	23
44	11	22
68	9	16
80	7	14
103	3	7
133	2	4

2. The Crystalline Part

Semper's cell or corneagen lies on the crystalline cone being compressed longitudinally. Its thickness is about 1 to 2 μ. The crystalline cone takes a bullet-like form in both the families and plays an important part in condensing the coming light from the upper corneal lens (Photo II, IV). Some authors reported erroneously that the Semper's cell produces only one crystalline cone in *Bombyx mori*, but in fact the cone is composed of four cells. The distal end of crystalline cone is surrounded with vitrellae and iris cells which connect with a rhabdome. The vitrella sometimes called a corneagenous cell is unstainable by pigment.

3. The Retinular Part

The retinular part is composed of a rhabdome, retinular pigment cells and retinular cells as seen in other moths. The pigment granules in the retinular pigment cells of both *Bombyx* and *Saturnian* eyes do not migrate downwards as far as the top of the rhabdomere, but in *Theophila* the pigment granules migrate and nearly touch the rhabdomere. It is the remarkable difference of the eyes of *Theophila* from those of other silkworms (Photo II, IV, V .

At a part of the rhabdome there is a pigmented portion named "rhabdome pigment" by YAGI (1938 .

4. The Tapetum

The tapetum which encloses the proximal end of the rhabdomere is considered to be an organ reflecting the light from upper part. It contains small branches of the trachea coming from the basement-membrane (Photo III, V, VI).

Table 4. The length of every part of the ommatidia

Species	Cornea	Crystalline part	Retinular part	Rhabdomere	Tapetum
Bombyx mori	14 μ	60 μ	192 μ	72 μ	24 μ
Theophila mandarina	11	50	200	70	22
Samia cynthia pryeri	20	66	484	120	40
Samia cynthia ricini	20	68	320	140	44
Actias artemis	22	70	580	152	44

Each length of above described parts is shown in Table 4.

III. Light and Dark Adaptation

1. External Changes in Light and Darksness

The light adapted eyes of *Bombycidae* are generally purplish black from the outer view, while those of *Saturniidae* have a blackish pupil in each center of them.

When the moths are putted in the dark condition, glows appear in the centers of compound eyes instead of the central pupils in the light condition.

Glows shine brilliantly to pale blue in *Bombycidae* and copper orange in *Saturniidae*.

2. Migration of Retinular Pigments

The adaptation of the eyes of moths to light and darkness is indicated by the migration of retinular pigments and most moths adapt completely to each environment during five to ten minutes. But, the *Bombyx* eyes cannot be adapted in such a short exposure and the retinular pigments migrate in very narrow range up and downwards.

This phenomena will suggest that the domestication has affected the adaptaion of the eyes of silkworm to light and darkness.

Some varieties of *Bombyx mori* have red-eyes or white eyes, etc, in which the adaptation is not recognizable easily from the outside.

The precise investigation of these varieties is now being conducted in the author's laboratory.

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摘　　要

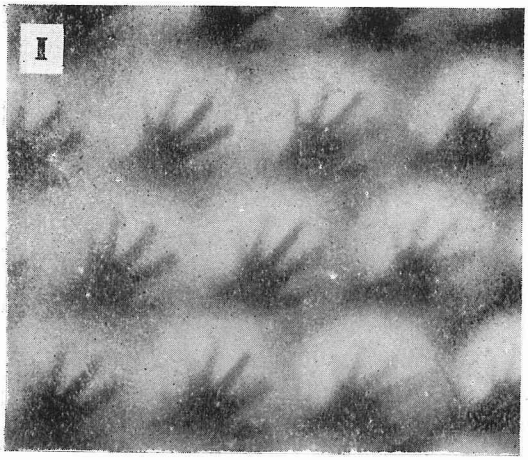
Bombycidae と *Saturniidae* は共に絹糸虫類として著名であるが，その成虫は生殖行動をなすだけで栄養摂取は行わない　かかる種類の蛾の複眼特にカイコガの如く domesticate されたもののそれは光刺戟をどのように感受するか構造的にも又機能的にも極めて興味のある問題である。しかし絹糸虫類の蛾の複眼については基礎的な研究は殆どない。

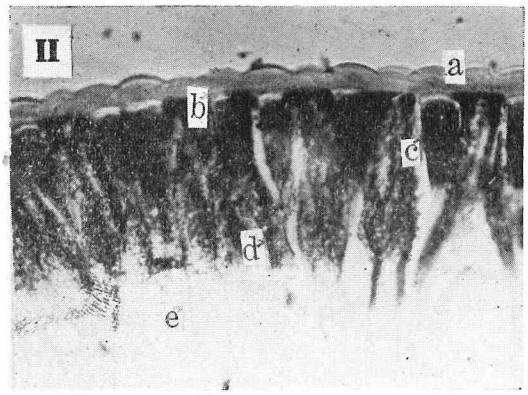
筆者は近年両科の蛾の複眼について研究を実施し，種々な知見をえたが，ここにはその結果の大略を，外部及び内部形態並びに光適応の項目下で予報した，詳細については引続き発表の予定である。

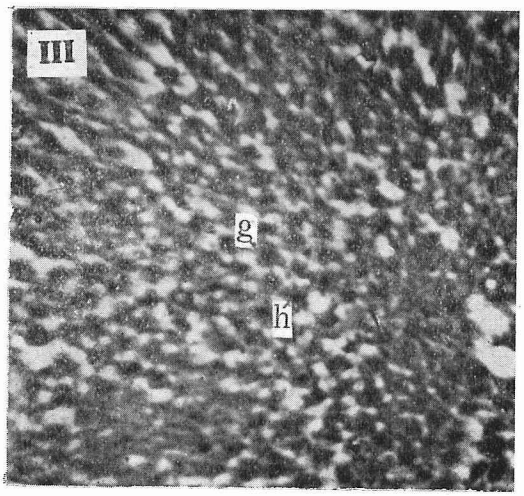
Explanation of Photoes

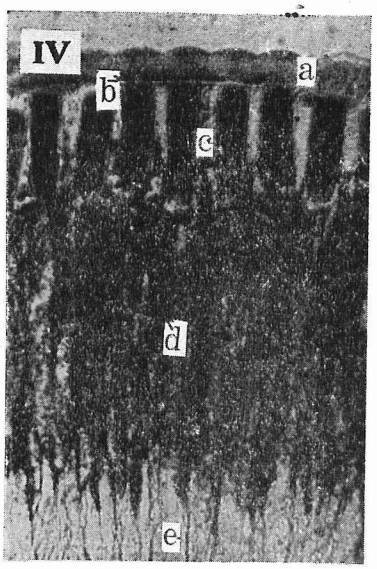
Ⅰ. Images of a human hand formed at the inner part of the corneal lens of *Antheraea pernyi*.
Ⅱ. Light adapted eye of *Bombyx mori* (longitudinal section).
Ⅲ. Tapetal part of the eye of *Samia cynthia ricini* (cross section).
Ⅳ. Light adapted eye of *Samia cynthia pryeri* (longitudinal section).
Ⅴ. Tapetal part of the eye of *Theophila mandarina* adapted in light (longitudinal section).
Ⅵ. Distal region of the eye of *Bombyx mori* (longitudinal section).

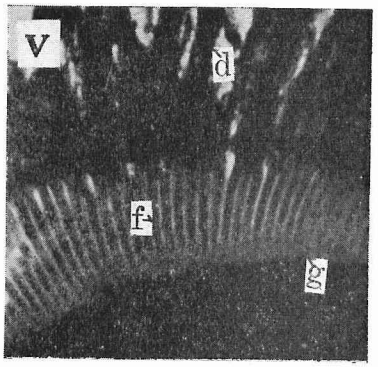
a : cornea　　b : Semper's cell
c : crystalline cone　　d : retinular pigment
e : rhabdome　　f : rhabdomere
g : tapetum　　h : rhabdome pigment
i : basement-membrane　　j : nervous system

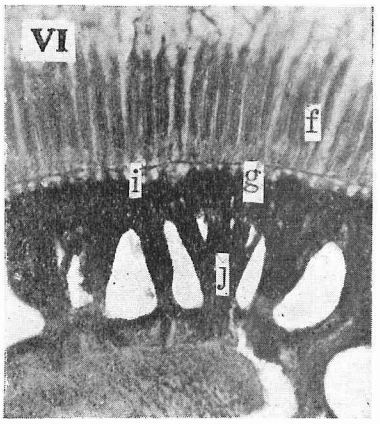












KOYAMA