

ON THE DOWNWARD MIGRATION OF THE RETINULAR
PIGMENTS IN THE COMPOUND EYE OF THE SILKWORM
MOTHS UNDER UNIRRADIATION OF LIGHT *

by

Nagao KOYAMA

(manuscript received Sep. 20, 1957)

Introduction

In the previous papers the author has already reported that the compound eye of the silkworm moths belonging to *Bombycidae* and *Saturniidae* show the daily rhythm of alternate adaptation to the light and the darkness in the natural condition and has demonstrated that the interval of persistence of adaptation is directly controlled by the light action. However, even in the absence of light, we can observe that the light adapted downward migration of the reticular pigments occurs, if the moths of both families are exposed to extreme low or high temperature (1), or ligated at the neck (2). Especially in the Saturniid moth the compound eye exhibits a daily rhythmicity of light adaptation (3) in the constant darkness during several hours in the forenoon. According to this phenomenon the author (1955) has pointed out that these downward migration of the pigments will be controlled physiologically by the same reaction caused by lowering metabolism, namely the lack of the air supply (2) or the cold and heat rigor (1), and it is certain that the moth in *Saturniidae* shows considerably lower vitality as being anesthetized in the daytime than in the night time (KOIZUMI, SHIBATA & KUBOTA, 1941; KURASAWA & KOYAMA 1950; TAKEDA, 1951, 1953; YAMAZAKI, NISHIMURA & YAMADA, 1953).

Here the question arises whether the downward migration of the pigments which occurs under the darkness takes place with the just same phase as that happens under the illumination. In the present paper the above problem which was preliminarily reported by the author (1975 a, b) has been analyzed.

The author expresses a gratitude to Prof. Dr. N. YAGI for his advices and also thanks to Dr. H. YAMAZAKI who sent the materials for the author's use, and to Missis R. KOMATSU and Mr. K. KOBAYASHI for their assistance.

Materials and Methods

Japanese strain of *Bombyx mori* (Shinkō) and *Antheraea pernyi* were used for the experiment. The pupae were protected under the constant darkness with the temperature of

* Contribution No. 35 from the Laboratory of Biology and Entomology, Textile and Sericulture, Shinshu University, Ueda, Japan.

25°C and the humidity of 75% (R. H.). The moths emerged from the above treatment were subjected to the conditions shown in each chapter. The fixation of tissue was done by applying Carnoy's solution. The thickness of sectioning was 15 μ . Majority of the tissues were unstained, minority being stained with Delafield's hematoxylin after depigmented by Grenacher's solution.

Results

Movement of the retinular pigments in the compound eye of the ligated moth

The moth of Shikō which had been confined at the dark chamber or exposed to one kilolux lamp light, for one hour respectively, were subjected to the conditions from A to D which is described in Table 1. They were fixed at 10 minutes intervals.

Table 1 Experimental methods

Appearance of the eye before treatment	Operations given	Conditions given	Adaptative degree of the eye in resulting moth
I. Dark adapted	A. ligation	light	light
	B. ligation	dark	light
	C. normal	light	light
	D. normal	dark	dark
II. Light adapted	A. ligation	light	light
	B. ligation	dark	light
	C. normal	light	light
	D. normal	dark	dark

The results from the superficial observation of the compound eye in the right column of Table 1 were completely coincided with the experiments previously observed by the author (1954, 1955).

The compound eye of the moth ligated at the neck exhibits the light adapted appearance without exception notwithstanding the condition was dark (I-B and II-B). The fact of noteworthy can be seen in I-B experiment in which the dark adapted eye turned into the light adapted type.

The degrees of downward movement of the retinular pigments in the respective régime are shown in Fig. 1.

I-A: After 10 minutes the glow of compound eye disappears changing into dark colouration. The migration index of the retinular pigments is 77% at 10 minutes and 100% at 20 minutes.

I-B: Under the absence of light the downward migration of the pigments occurs evidently, exhibiting a completely light adapted phase at 30 minutes. The velocity of the pigment movement is much quicker than the normal light adaptation (I-C) and slower than the case of I-A which is assumed to show faster migration because the light stimulus was added upon the ligating operation.

The eye of completely light adapted type in the above experiment is entirely the same

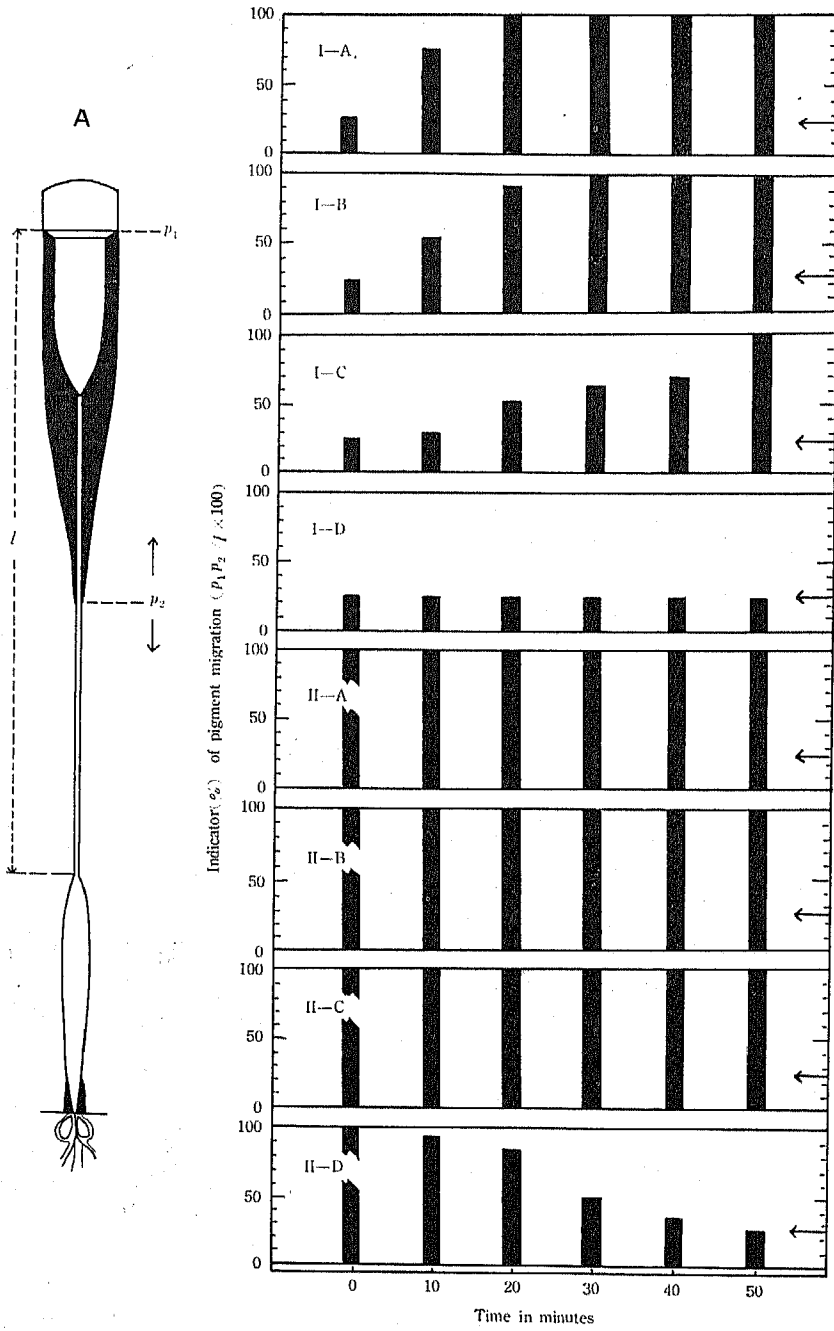


Fig. 1 Migratory degree of the reticular pigments of Shinkō strain in each experiment which is shown in Table 1.

A; diagrammatic figure of an ommatidium.

Migration index; $P_1P_2/l \times 100$ (%)

Arrows in the right ordinate show the index in the case of the complete dark adaptation.

as in the case of normal light adapted eye concerning the distribution of the pigments (I-C, Photo 4), but the nuclear movement is different. In the normal light adaptation nuclei of the reticular pigment cell are situated near at the proximal part of the crystalline layer, while in the eye of ligated moth some nuclei are located at an inner position than the normal one (Photo 5).

I-C: This is a normal case of light adaptation. The migration index of the pigments is 31% at 10 minutes, 53% at 20', 60% at 30', 69% at 40' and 100% at 50' (Photo 1); the increasing feature of the index value shows almost an S-shaped curve, but the velocity of the pigment migration is much slower than in either case of I-A or of I-B. From external observation the glow can hardly be distinguished at 20 minutes and disappears at 30 minutes.

I-D: The pigments in the completely dark adapted eye never move when the moth is kept under the darkness.

II-A and II-C: There happens no change in the pigment distribution of completely light adapted eye, if it is exposed succeedingly to the light.

II-B: The ligated eye which shows the light adaptation exhibits no upward pigment migration, even though it is subjected to the darkness.

II-D: This is the process of a normal dark adaptation. The index value of the pigment migration is measured as 95% at 10 minutes, 86% at 20', 50% at 30', 36% at 40' and 20% (complete light adaptation, Photo 2) at 50'.

The upward migration of the pigments is recognizable to be the quickest within the range of 20 to 30 minutes.

In addition to the above experiments, two researches were carried out, viz. the one in which the moth having the completely light adapted eye was continuously confined in the darkness after ligated between the thorax and the abdomen, and the other in which the light adapted eye, being separated together with the head from the body, was laid under the absence of light.

According to the histological observation on the both treatments the compound eye was ascertained to be unable to retain the perfect dark adaptation but to show more or less light adapted phase covering the pointed end of the crystalline cone in the pigment distribution (Photo 3).

Migratory phase of the reticular pigments in the compound eye of the light adapted appearance which is recognizable under the constant darkness

A half number of individuals of *Antheraea pernyi* were kept under the constant condition and the rests were exposed to the natural environment. The external colour manifestations of the eye of both groups were changed to the dark adaptive phase and to the light adaptive one alternatively with daily rhythm.

In all these instances we know that in the case of A the downward migration of the pigments has occurred during a definite period from 10 a. m. to 2 p. m. while in B from

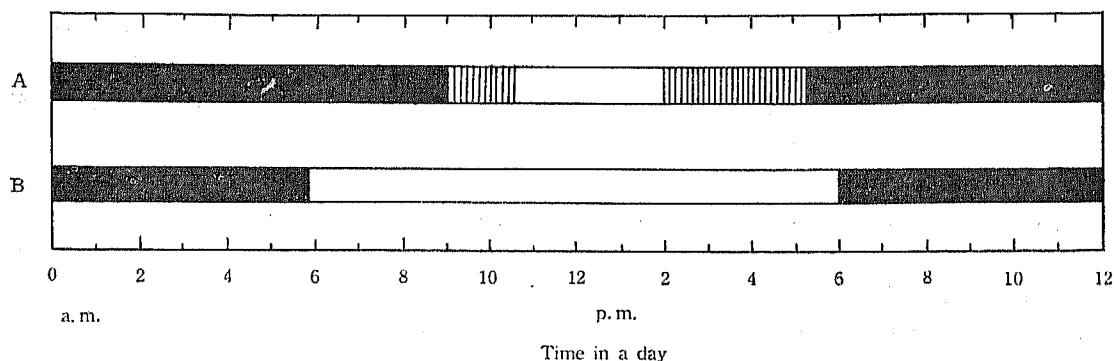


Fig. 2 Diel change of the outside compound eye of *Antheraea pernyi* when the moth was maintained under the constant darkness (A) and the natural condition in mid-August (B)
Black; dark adaptation, Lined; intermediate adaptation, White; light adaptation.

6 a. m. to 6 p. m. The light adapted phenomenon in A would be caused by an endogenous influence, because the environmental conditions were kept in constant, and that in B would be brought by the light stimulus (sunrise, about 6 a. m.; sunset, about, 6 p. m).

The eye at 12 a. m. in A experiment was obviously a light adapted type, but its migratory phase of the pigments differed conspicuously from the eye observed at the same time in B experiment, viz. the migration index of A was 32% (Photo 9), while B was 72% (Photo 7). Therefore it is certain that the downward migration of the reticular pigments caused by an endogenous stimulus under the constant darkness is not accomplished in perfection (migration index, about 70%). Furthermore the characteristic fact in such an eye is a movable phase of the nucleus of basal pigment cell. In the light adapted natural eye of *Antheraea* moth the basal nuclei scarcely move up to the distal surface of basement membrane, but in the eye of A case a few nuclei migrate upwards through the basement membrane (Photo 6).

Thus the author wants to describe conclusively that the downward migration of the reticular pigments occurs without light stimulus and its migratory phase differs somewhat from the normal light adaptation.

Summary

In the present paper an account is given on the pigment migration in the eye of the light adapted type which appears in the dark environment. The compound eyes used for the experiment are those of *Bombyx mori* (Japanese strain, Shinkō) and of *Antheraea pernyi*.

The results obtained are summarized as in the followings.

1. The moths ligated at their neck exhibit without exception the light adapted appearance regardless to the succeeding environment. Even in the darkness the distribution of the reticular pigments extends perfectly over the retinal part showing no difference from that of the normal light adapted eye. However the velocity of the pigment movement is

much faster than that of the normal one and the nuclei of retinular pigment cells, being usually located just under the crystalline cone, are situated almost near at the middle part of the retinal part.

2. When the moth which shows the light adapted eye is laid under the darkness after decapitation or ligation between the thorax and the abdomen, it can not attain the complete dark adaptation. The retinular pigments cover the pointed end of crystalline cone.

3. The migratory phase of the retinular pigments in the light adapted type of *Antheraea* moth differs considerably from the type of a normal light adapted eye. In the former the index value of downward migration of the pigments is 32% while 72% in the latter.

4. In the normal light adapted eye of *Antheraea pernyi* the basal nucleus hardly moves, while in the light adapted type of the eye caused by an endogenous stimulus a few nuclei sometimes protrude its one part through the basement membrane.

Literatures Cited

- KOIZUMI, K., SHIBATA, K. & K. KUBOTA : Publ. from Agric. Formosa, 6 : 1-253 (1941).
 KOYAMA, N. : J. Shinshu Univ. Ser. A, 4 : 15-64 (1954).
 ———— : Ibid, 5 : 1-54 (1955).
 ———— : J. Seric. Sc. Jap., 26(3) : 231 (1957 a).
 ———— : Print on Lect. in the meeting of Ecol. Soc. Jap., 15 (1957 b).
 KURASAWA, Y. & N. KOYAMA : Coll. & Breed. 12(1) : 278-280 (1950).
 TAKEDA, H. : Res. Rep. Text. & Seric., Shinshu Univ. 1 : 21-28 (1951).
 ———— : Ibid, 3 : 35-39 (1953).
 YAMAZAKI, H., NISHIMURA, K. & K. YAMADA : Lect. J. Seric. Sc. Jap., Chūbu branch,
 7 : 17 (1953).

Explanation of the Plate

1. Perfect light adaptation of the compound eye of *Bombyx mori*.
2. Ditto, perfect dark adaptation.
3. Dark adaptation in the eye of the decapitated individual.
4. Pigment distribution in the eye of light adapted type which is seen in the darkness if the moth is ligated at the neck.
5. Ditto, showing especially the position of the nuclei in the retinular pigment cell.
6. Movement of the nucleus of the basal pigment cell in *Antheraea pernyi*. This phase is recognized in the compound eye of light adapted appearance which happens spontaneously in the constant darkness.
7. Completely light adapted eye of *Antheraea pernyi*.
8. Complete dark adaptation in the eye of the some species.
9. Pigment migration in the eye of light adapted type which is brought by an endogenous stimulus in the constant darkness.

Abbreviations in Photographs

- a : Retinular pigment cell
 - b : Nucleus of the retinular pigment cell
 - c : Nucleus of the basal pigment cell
 - d : Rhabdomere
 - e : Basement membrane
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