115. *Function of the Brain-Suboesophageal Ganglion Complex in the Silkworm, Bombyx mori*

By Takeshi NAGATOMO

Faculty of Agriculture, Kagoshima University

(Comm. by Yô K. OKADA, M.J.A., July 12, 1956)

In the silkworm the quantitative characteristics such as length of larval and pupal life, body-weight, weight of cocoon layer, egg production, etc. differ according to race and sex. Genetically, the worms of late maturity differ from those of early maturity, in greater body-weight and weight of cocoon layer, and in a later emergence of moths producing larger amounts of eggs than those of early maturity. The same thing is noticed when the male and female of the same race are compared: females are greater in body-weight and weight of cocoon layer and later in emergence than males. But what physiological mechanism causes such a phenomenon has not been made clear at all.

In the experiment of parabiosis between the pupa of the race which has a short pupal period and that of a long period, it has been noticed that the pupal period of the former is somewhat lengthened and that of the latter is shortened. This fact suggests the existence of a certain late-maturing factor in the body of the late-maturing pupa. It has shortly been found, by means of organ transplantation, that brain-suboesophageal ganglion complex plays an important part in forming quantitative characteristics.

Materials and Methods

In the experiments of parabiosis, the writer, employing the male pupae of EK and Fm, which were pupated at the same time, connected them by means of a small glass-tube, and removed the earlier-emerged moth of a pair from the connection at the moment of emergence.

For comparison of the actions of brain-suboesophageal ganglion complex between the different races, the implantation method was applied, using E16 of late-maturing and N3 of early-maturing as donor and their hybrid as recipient. For comparison of the actions of the complex between the male and the female of the same race, N1 was used as donor and J112 as recipient. Young 4th-instar larvae were selected both for donors and recipients, and one complex of a donor was implanted into the pregonadal segment of recipients.

Those implanted larvae which were to be compared with each other

were reared in aggregate after marking each of them with colours according to the different donors, so that they might be reared under equal conditions. In measuring the weight of pupa, the writer selected the middle part of the pupal period when least change happens in the body-weight. He calculated the pupal period by watching pupation and emergence at intervals of every four hours in a room of constant intensity of illumination after mounting, so that the moths might freely emerge without distinction between morning and evening.

Experimental Results

Table I shows the result of parabiosis between the male pupae of EK and those of Fm.

Table I. Pupal period in parabiosis

Parabiosis	No. of pairs of pupae connected	Pupal period (hours)			
		Pupa	No. of moths obtained	$\bar{x}$	s
Fm ♂ ↔ Fm ♂	10 (Control)	Fm ♂	16	175.0	0.32
EK ♂ ↔ Fm ♂	20	Fm ♂	18	185.4	1.74
		EK ♂	17	270.2	1.93
EK ♂ ↔ EK ♂	10 (Control)	EK ♂	18	294.6	2.42

$\bar{x}$: Means

s : Standard deviations

It can be noticed that the pupal period of early-maturing Fm was lengthened by 10.4 hours and that that of late-maturing EK, on the other hand, was shortened by 24.4 hours compared with the corresponding control.

Table II shows the quantitative characteristics of donors used in an experiment for implanting complex.

Table II. Quantitative characteristics of donors

Donors	No. of individuals	Weight of cocoon layer (cg)	Pupal period (day)
K16 ♂	100	35.3	15
N3 ♂	100	21.2	10
N1 ♀	100	31.5	13
N1 ♂	100	29.7	12

In the table the cocoon layer was weighed in a lump, and the pupal period was shown by the number of days between the day on which the largest number of worms pupated and that the largest number of moths emerged.

Table III shows the result of implanting the male complex of E16 and that of N3 into their hybrid.

Table III. Implanting* experiment with the complex of E16 and N3

Experi- mental section	Recipients	Donors	No. of larvae opera- ted	Weight of cocoon layer (cg)			Weight of pupa (g)			Pupal period (hours)		
				No.	$\bar{x}$	<i>s</i>	No.	$\bar{x}$	<i>s</i>	No.	$\bar{x}$	<i>s</i>
A	(E16 $\times$ N3) φ	E16 σ	20	17	27.7	1.08	17	1.61	0.184	16	278	1.26
B		N 3 σ	20	18	26.5	1.04	17	1.53	0.183	17	272	1.98

No.: Number of materials obtained from operated larvae respectively

* Operation was done on the 3rd day of the 4th-instar.

In the specimens implanted with the complex of late-maturing E16, it can be noticed to be always greater the quantitative characters of the recipient than in those with an implant from the complex of early-maturing N3. Table IV shows the result of implanting the complex of both the female and the male of N1 into the female of J112.

Table IV. Implanting* experiment with the complex of N1

Experi- mental section	Recipients	Donors	No. of larvae opera- ted	Weight of cocoon layer (cg)			Weight of pupa (g)			Pupal period (hours)		
				No.	$\bar{x}$	<i>s</i>	No.	$\bar{x}$	<i>s</i>	No.	$\bar{x}$	<i>s</i>
A	J112 φ	N1 φ	30	28	31.9	1.41	27	1.73	0.175	25	303	1.84
B		N1 σ	30	26	30.7	1.17	25	1.67	0.179	25	289	1.16

* Operation was done on the 3rd day of the 4th-instar.

Here the implantation of the female complex is observed to augment the quantitative characters of the recipient more than the male complex. In the last two experiments, it was also noticed that the recipients of Section A in Tables III and IV laid more eggs than Section B.

The larval period of the 5th-instar of the recipients of Section A is almost the same as Section B. But on the other hand, it was observed that the recipients implanted with the complex of the late-maturing or female donors, required more food in the period of that instar than those implanted with the complex of early-maturing or male donors. Judging from the above-mentioned fact, it can be said that more increase of quantitative characters occurred in the case of the recipients implanted with the complex of male of E16 or female of N1 by taking larger amounts of food, as compared with the recipients implanted with the complex of male of N3 or that of N1. But when, in every experiment, the brain and suboesophageal ganglion were separately implanted, the writer could not notice the above-mentioned effect that the implanting produces upon quantitative characters.

Discussion and Conclusion

Judging from the above-mentioned results, it may be said that some hormone-like substance which plays a part in the formation of the quantitative characters is secreted from some part of the brain-suboesophageal ganglion complex in the silkworm and that the secretion of the complex from the late-maturing race or from the female is stronger than that from the race early-maturing or from the male.

According to the measurement of the size (length $\times$ width) of the suboesophageal ganglion of larvae, it was found that the ganglion of the late-maturing race or of the female is greater than that of the early-maturing race or of the male. Therefore, it seems that the strength of the action of the above-mentioned complex depends on the quantity of the secretory substance. As to the participation of the complex, there seems to be either of two possibilities: that a hormone-like substance directly brings about the increase of quantitative characters, or that the substance helps indirectly to accelerate the action by stimulating another kind of inner secretory gland (if any) that regulates the quantitative characters. At any rate, it seems that such a function of the complex can be explained by applying Fukuda's hypothesis on the determination of voltinism. That is, the result of the experiment is understood if it is assumed that a region in which hormone-like substance is secreted is probably that of suboesophageal ganglion, and that the brain regulates the secretion of suboesophageal ganglion through the oesophageal connectives.

The existence of sex hormone in the insect has not been confirmed. It has not been discovered at all from which region comes the secretion that causes the difference of body-weight between the male and the female. It is very interesting to see the experimental result as confirming the belief that the secretion from the brain-suboesophageal ganglion complex generally not only participates in the formation of racial differences in quantitative characters, but also may play a role, like the sex hormone, in causing the difference of body-weight of the male and the female of the same race.

As a rule, in the case of silkworm the male moth has a larger antenna than the female and the pattern of the wing of the male is of darker colour than that of the female. So far as the above-mentioned experiments are concerned, the influence caused by the implantation with the complex of male donors on the antenna or wing-pattern of female recipients is not recognized at all.

Reference

Fukuda, S.,: Proc. Japan Acad., **27**, 582-586 (1951).