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The behavior of *Oncomelania nosophora*, the vector snail of schistosomiasis in Japan, in total darkness*

Kazuo YASURAOKA

Department of Parasitology, National Institute of Health, Tokyo

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An understanding of the behavior of schistosome-bearing snails must rank high among those aspects of molluscan biology which are important to rational control, whether ultimate means of this control be biologic, naturalistic or chemical. Although it is well known that Oncomelania snail has a nocturnal habit (Pesigan et al., 1958 ; Nakao et al., 1958), no informations are available concerning the behavior of the snail in total darkness. Ullyott (1936) devised a technic for recording the direction of the movement of flatworm, *Dendrocoelum lacteum*. This technic consisted of making the animal record its own track. Chuan (quoted from Su, 1957) used a similar technic in the study of behavior of *Oncomelania hupensis*, the vector snail of schistosomiasis in China, to light. The present investigation is an attempt to explore the behavior of *O. nosophora* in total darkness by using Ullyott's technic with slight modifications.

Materials and Methods

O. nosophora used in this study came from the field collection at the endemic area in Yamanashi Prefecture. Only adult snails which were actively moving when placed in aerated tap water were selected for the experiment.

An enameled tray of 40 cm long and 35 cm wide containing aerated tap water up to 5 cm from the bottom was used as an observation

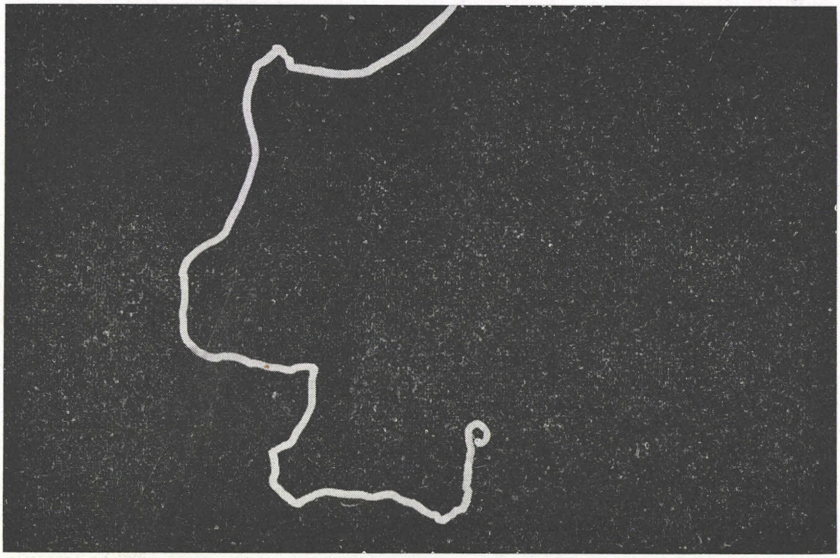

Fig. 1. Reproduction of the track of *O. nosophora* by Ullyott's method with slight modifications. (For description see text.)

* Studies on the behavior of *Oncomelania nosophora*. No. 5.

aquarium. The bottom of the aquarium was covered by a sheet of clean glass, on which the snail crawled leaving a slime trail behind it. This track was normally quite invisible, but if the glass plate was put into a 10 % water suspension of alminocilicate, the particles became entangled in the mucus, so that after gentle agitation of the plate in clean water the path traced out by the snail stood out as a white line (Fig. 1). The plate was then dried and prints were made from it so that a permanent record could be kept. With this method no time marking could be made on the record, but a very exact reproduction of the movements was obtained even in total darkness. In order to record the track and its time relations, on the other hand, the track made by the snail in the light was represented by a pencil line on squared paper. Corresponding squares had been ruled with a diamond point on the back side of the glass plate. On these records the time intervals were marked. By a comparison with the direct print of the mucous trail of the snail, an accurate record of the track and its time relations was produced. The distance of locomotion of the snail was measured by means of a curvimeter and the velocity (mm/min) was determined. The turns were added up irrespective of whether they were right or left turns and the rate of change of direction (angular degrees/min) was calculated. The method of finding the values of the angles α, β, γ, δ, ε, is shown in Fig. 2.

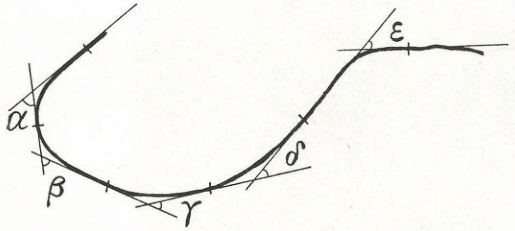

Fig. 2. Method for obtaining the numerical value of the rate of change of direction (r. c. d.). (For description see text.)

In each experiment observations were made on one snail only. Every experiment was considered to be at end when the snail reached the side of the aquarium, for stimulation by contact with the side might have introduced into the behavior other factors than those which were due to stimulation by light. The aerated tap water used was filtered to ensure that no food particles could disturb the behavior of the snails.

All the experiments were done in the dark room using electric light shining from above the snail. The source of light used was a 100-volt and 30-watt fluorescent lamp (day-light type). A heat filter, 4 cm thick, filled with distilled water, was mounted between the lump and the aquarium. The light intensity of illumination at the surface of the bottom of aquarium was adjusted to 100 lx. throughout the period of experiment.

Results

Experiment 1

One snail was put into the aquarium and as soon as the snail begun to creep the light was switched off. After 20 minutes, the snail was removed from the water and the track recorded. This experiment was done with 10 individual snails, and the average velocity and the average rate of change of direction (r. c. d.) were each determined. The same observation was made in the light for comparison with the behavior in the dark. During the observation period the water temperature varied between 18°C and 19°C.

The results are given in Figs. 3 and 4 and summarized in Table 1. The r. c. d. in the dark was significantly larger than that of snails in the light ($P<0.01$), whereas the velocity in the dark and in the light were not significantly different ($P<0.01$). As may readily be seen from Fig. 3, the r. c. d. was particularly large immediately after switching off the light and the values fell off as time went on. This initial increase in r. c. d. might be ascribed to the so-called "shadow reaction" to rapid decrease in light intensity and the following decrease in r. c. d. under constant stimulation to sensory adaptation in the eyes.

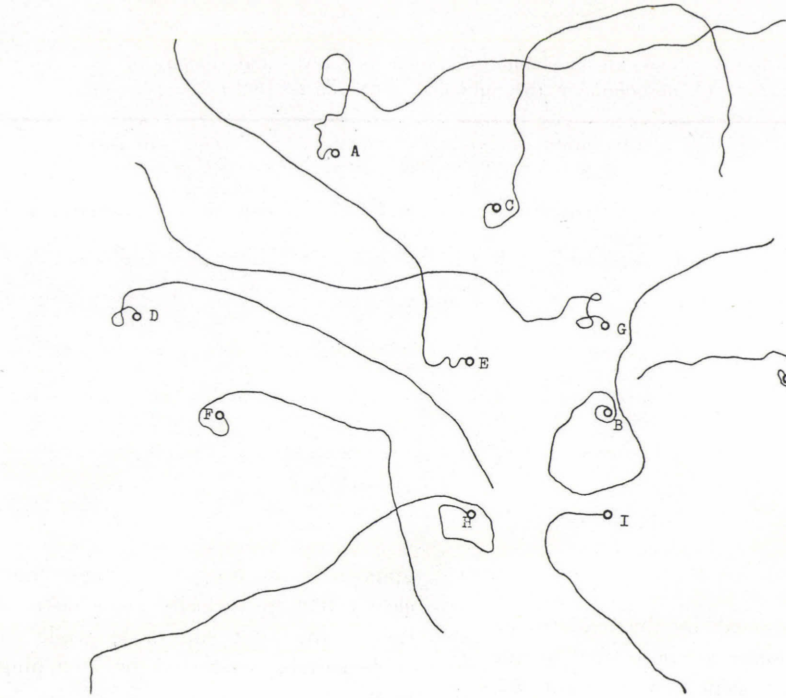

Fig. 3. Track of *O. nosophora* in total darkness for a period of 20 minutes after switching off the light (18–19°C). The small circles show the starting point of locomotion.

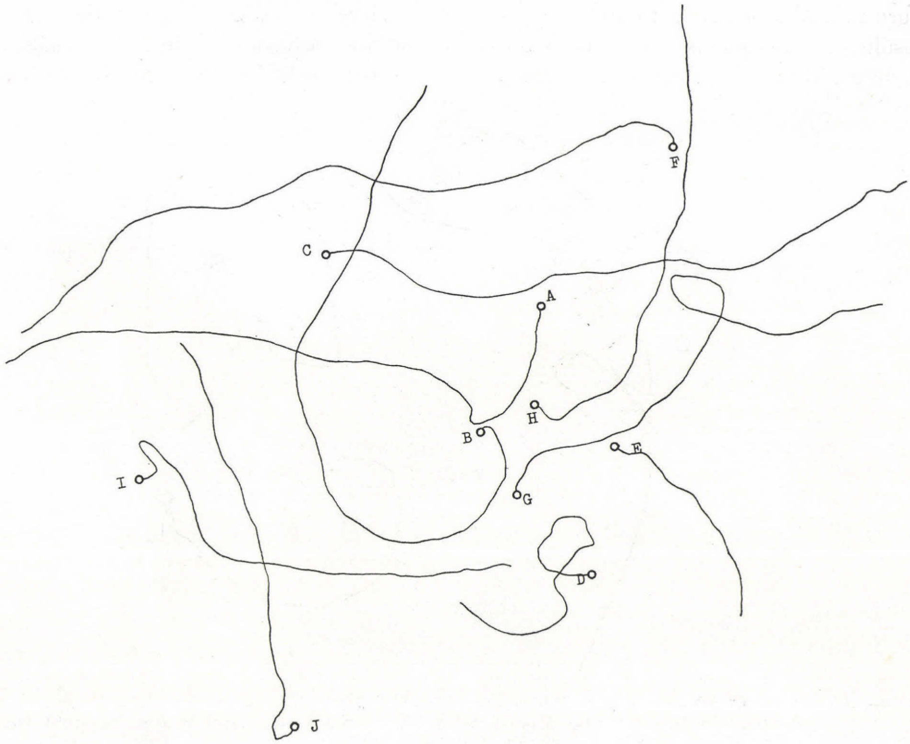

Fig. 4. Track of *O. nosophora* in the light for a period of 20 minutes (18–19°C). The small circles show the starting point of locomotion.

Table 1. The rate of change of direction (r. c. d.) and velocity of *O. nosophosa* in the light and in the dark (18–19°C)

Snail	In light		In dark	
	Velocity (mm/min)	r. c. d. (angular degrees/min)	Velocity (mm/min)	r. c. d. (angular degrees/min)
A	11.0	9.4	8.8	27.9
B	9.4	15.8	8.4	49.2
C	8.4	4.4	7.6	20.7
D	5.5	27.3	7.0	25.3
E	3.0	2.4	6.5	28.3
F	9.6	10.3	6.3	22.1
G	8.1	19.6	9.1	37.4
H	6.6	6.6	8.5	23.2
I	6.4	16.4	4.5	6.3
J	5.8	8.1	4.3	25.1
Average	7.4	12.0	7.1	26.6

Experiment 2

The procedures applied in this experiment were essentially the same as those used in the previous experiment, except that the light was switched on and off at intervals of 5 minutes during the observation period. The water temperature ranged from 15°C to 16°C.

The results of experiments with 3 individual snails are shown in Fig. 5, which are illustrated graphically in Fig. 6. These figures show clearly that the velocity bears no marked relation to the light and dark, while the r. c. d. is remarkably increased by switching off the light.

Experiment 3

Here, in order to avoid the shadow effect on the behavior of snails, 5 snails were kept in the dark for 18 hours before experiment.

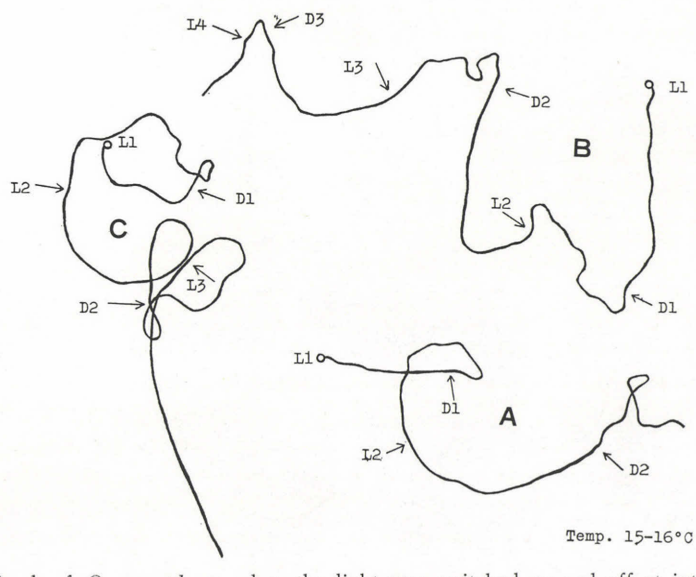

Fig. 5. Track of *O. nosophora* when the light was switched on and off at intervals of 5 minutes (15–16°C). The arrows with "D" mark the point where the light was switched off and those with "L" lighting point.

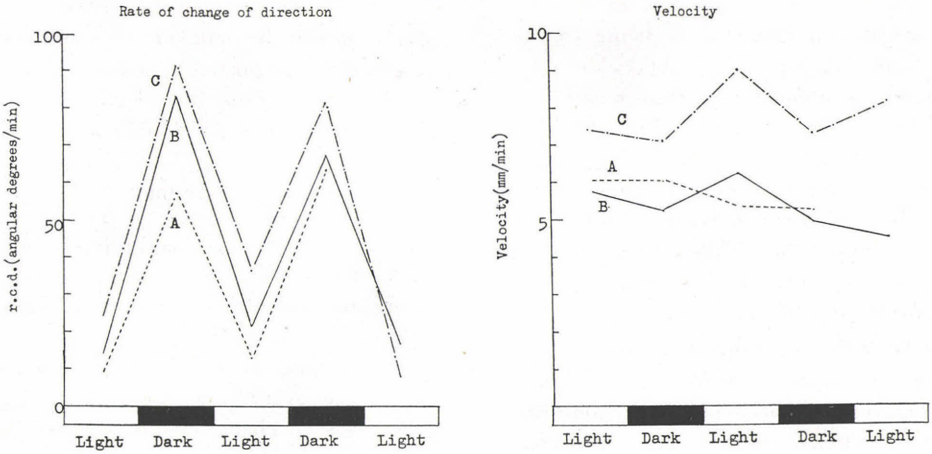

Fig. 6. Graph showing the rate of change of direction (r. c. d.) and velocity of *O. nosophora* when the light was switched off and on at intervals of 5 minutes.

Table 2. The rate of change of direction (r. c. d.) and velocity of dark- and light-adapted *O. nosophora* in the dark and in the light respectively (15–16°C)

Snail	Dark-adapted snails in the dark		Light-adapted snails in the light	
	Velocity (mm/min)	r. c. d. (angular degrees/min)	Velocity (mm/min)	r. c. d. (angular degrees/min)
A	5.2	9.3	9.9	16.6
B	11.2	36.1	9.1	27.6
C	10.1	45.4	6.8	30.5
D	9.8	26.3	12.2	29.0
E	13.0	47.5	7.5	18.0
Average	9.9	32.9	9.1	24.3

The snails were then each put into the aquarium without exposing them to light and subjected in the dark for 10 minutes to obtain their track. For comparison with these dark-adapted snails, other 5 snails were kept in the light for 18 hours and then they were each put into the aquarium in the light without submitting them to darkness. The water temperature during the experiment was 15–16°C.

The results of two sets of experiments, with the dark-adapted snails and with light-adapted snails, are shown in Table 2, which brings out the fact that the r. c. d. of the dark-adapted snails was still significantly larger than that of light-adapted snails ($P<0.05$), whereas no significant difference in the velocity was observed between the dark- and light-adapted snails ($P<0.05$).

Discussion

Ullyott (1936) devised for the first time a method by means of which a direct print of the track of flatworm, *Dendrocoelum lacteum*, on a glass plate could clearly be obtained. He put the glass plate, on which the animal had crawled leaving a slime trail behind it, into a fine watery suspension of talc powder. Chuan (1957, quoted from Su, 1957) used a fine soil, which is a speciality of China, for talc powder to obtain a direct print of the mucous trail of *O. hupensis*. In the present study alminocilicate was chosen in place of talc powder or a fine soil because it is a common medicine for the stomach and therefore easily obtainable. The track of *O. nosophora* was thus readily and clearly obtained as shown in Fig. 1. This method, or a modification thereof, is applicable to aquatic schistosome bearing snails such as *Bulinus*, *Biomphalaria* and *Australorbis*, and to probably many other snails. In a single experiment in this laboratory a clear track of *Biomphalaria alexandrina* and *A. glabratus* has been recorded by using this methcd.

The present author reported in a previous paper (1955) that the behavior of *O. nosophora* to lateral (directional) stimulation of light could be considered as a klinotaxis or a tropotaxis because of the form of the cephalic eyes and of the orientation to the beam of light and that the snail showed a shadow reaction to rapid decrease in light intensity, while no any response took place to rapid increase in light intensity. In the present study, when the light shining on the snail was switched off, while everything else was kept constant, there was no change in the velocity, but there was a sudden increase in the r. c. d.. According to the categories of animal behavior defined by Fraenkel and Gunn (1961), there was no ortho-kinetic response, but there was an increased r. c. d. resulting from switching off the light, a klino-kinetic response. The r. c. d., however, begun to fall as time went on. This decay in the response in spite of the constancy of the physical stimulus suggests that a process of adaptation is occurring. Further work needs to be done in order to ascertain whether this klino-kinetic response and the adaptation associated with it can cause aggregation of the snail in a suitable gradient of light.

Komiya et al. (1962), having made a study for the standardization of quantitative test of the susceptibility of Oncomelania snails to molluscicides, recommended that the temperature at which the snails are in the solution should be a constant one such as 25°C. However, if there is any difference in the amount of locomotion of the snails between in the light and in the dark, the test might not be performed in the dark as in an incubator. As to this point, it may be left out of consideration because it is demonstrated above that no significant difference in the velocity of the snails is found between in the light and in the dark.

Summary

A very clear and exact reproduction of the movement of *O. nosophora* was obtained by using the Ullyott's method with slight modifications.

If the light shining on the snail was switched off, while everything else was kept constant, there was no change in the velocity, but there was a sudden increase in the rate of change of direction (r. c. d.). There was no ortho-kinetic response, but there was an increased r. c. d. resulting from switching off the light, a klino-kinetic response. This initial increase in r. c. d. fell off under constant stimulation owing to adaptation.

Acknowledgement

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ミヤイリガイの行動，とりわけ暗黒下のそれについて

安 羅 岡 一 男

(国立予防衛生研究所寄生虫部)

Ullyott (1936) は *Dendrocoelum lacteum* の行動軌跡を記録する一新方法として，ガラス面上をあるかせた後にガラス板を滑石粉浮遊液中に入れ，動物があるくと共に分泌された粘液に付着させた．全松英（蘇徳隆，1957 より引用）は *Oncomelania hupensis* の行動軌跡を記録するのに滑石粉ではなく細泥浮遊液を用い，さらにこれを methylene-blue で染色している．著者はこれらの滑石または細泥浮遊液に代えて珪酸アルミニウムを用い，染色せずにきわめて明瞭なミヤイリガイの行動軌跡を得た．このようにして得られた軌跡について単位時間におけるミヤイリガイの行動の方向変換の角度の和(r. c. d.)および速度を算定した．

完全な暗黒下と，上方から 100 lx になるように螢光灯を照射した明下の両者における速度と r. c. d. を比較すると，速度は明下で 7.4 mm/min，暗黒下で 7.1 mm/min でいちじるしい差は認められなかつたが，r. c. d. は明下で 12.0 degrees/min，暗黒下で 26.5 degrees/min を示し，暗黒下における r. c. d. は明下のそれの2倍以上であつた．この r. c. d. の上昇はとりわけ消灯直後に顕著で，その値は時間の経過とともに低下した．最初の r. c. d. の上昇はいわゆる陰影反応によるもので，続いて見られた r. c. d. の低下は刺激に対する適応によるものと解される．5分毎に光を点滅した場合，暗黒下の r. c. d. は明下のそれの約5倍の値を示した．

それぞれ暗適応および明適応された貝の両者で r. c. d. を比較した場合においても，それはやはり暗黒下において約 1.4 倍高くあらわれた．すなわち，ミヤイリガイは光度の増加および減少に対して ortho-kinetic response は示さないが，光度の減少に対してあきらかな klino-kinetic response を示した．