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Relation between activity and glycogen contents of the Japanese loach[1)]

By

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I. Introduction

In spite of the great progress of study, having been made in internal metabolism of an animal body and in external manifestation of its behavior, we zoologists now have only little knowledge about the distinct connection between the metabolism in an animal body and its behavior. Animals' behavior is closely related to their environment, and in order to indicate this behavior such a term as "taxis" has been employed. But if we want to recognize its materialistic bases, we cannot help connecting it to the metabolic system inside an animal body. From these view-points it may be said that we can not acquire any systematized knowledge about the behavior without knowing the intimate connection existing among the environment, behavior and metabolism (MORI, '45, '48-1).

Our experiment was performed in order to make these connections clear. We want to deal with two problems in this paper, using *Misgurmes anguillicaudatus* (CANTOR) as material. These are daily changes of glycogen quantity associated with the daily periodic movement, and the relation existing between the change of glycogen contents and the activation of the loach, when it is fed after a long period of hunger.

II. Daily periodic activity of the loach.

Observations about the daily periodic activity were performed from May to June and from October to November, 1947. Seven loaches were kept in a large glass vessel (diameter 30 cm, height 15 cm) containing 2500 cc water, and several stones were put into it for the fishes to refuge beneath them. The vessel was placed in the calm laboratory under diffused day-light, and the water temperature was left unregulated. In all cases, the loaches had been cultured for about 4 weeks before the observations were begun. As for food, freshwater oligochaetes were used, and we always took care of maintaining the adequate quantity and freshness of food materials.

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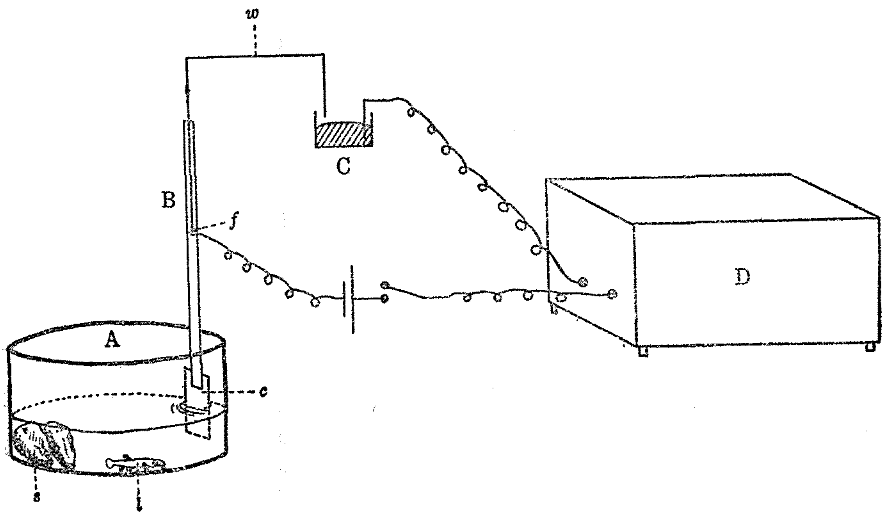


Fig. 1 Apparatus for recording the relative activity of the loaches.

A: Glass vessel containing the loaches (*l*) and the stones for their shelters (*s*).

B: Bamboo pendulum, by whose swing the electric circuit is made off or on.
c, celluloid plate; *f*, fulcrum; *w*, copper wire.

C: Mercury contacts.

D: Recorder of the numbers of electric contacts (Richard's type)

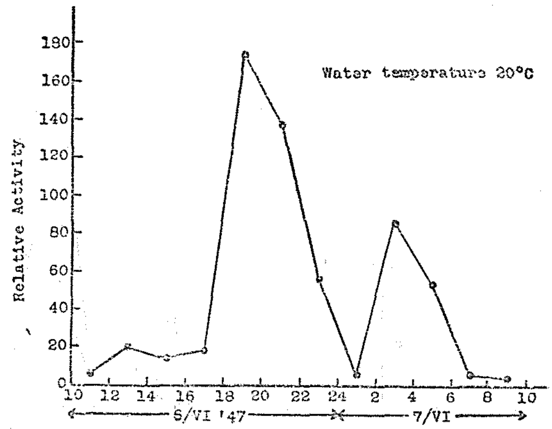
The apparatus used for our work is shown in Figure 1.

The water disturbances induced by the movements of the loaches made the pendulum (B) swing to and fro, and consequently the electric circuit is made off or on at the contact C, and this switching can be recorded on the cylindrical drum, rotating once a day in the recorder of the numbers of electric contacts (D). This recorder is that widely used in meteorology. The relative activity of the fishes was thus obtained.

An instance of the typical mode of periodic activity is shown in Figure 2. It is obvious that the activity of the loaches is nocturnal, having 2 peaks a day, the one after the sunset and the other after the midnight. The activity curve demonstrated in Figure 2 shows, as above mentioned, a normal case when the aimals are well fed. However, as they become hungry, the activity falls off, and at last the periodic movement almost disappears.

The type of this activity is exogenous (PARK, '40), controlled by the daily march of the solar illumination, because the animals lose their periodicities of activity instantly when they are subjected to constant darkness.

Fig. 2 Daily periodic activity of the loach (relative activity of 7 fishes male and female)



III. Relation between daily change of glycogen contents and daily periodic activity

Glycogen in liver and muscle was analysed quantitatively. Experiments were performed during the periods of October 17-18, 1947 and May 14-15, 1948. Only the male animals, cultured as mentioned above, were used in these experiments. Every 3 hours 5 fishes were killed by cutting their heads, and the livers and the pieces of muscles (0.1-0.2 gr) were severed, and each material was treated separately by using SUDO's method (SUDO, '41). One of the results obtained is shown in Figure 3.

It may be concluded from this Figure that;

(a) The change of glycogen quantity in a liver shows 2 peaks a day, those before the sunset and the sunrise, the latter being greater.

(b) The glycogen quantity in a muscle also shows 2 peaks a day, that is, before and after the midnight, the latter being greater,

(c) These periodicities seem to be closely correlated to the periodic activity, which has 2 peaks a day.

When the loaches are reared without food for about a month,[2] the daily periodicity in the glycogen quantity becomes obscure in livers, but in muscles the periodicity seems to be recognizable, attaining to the maximum before the sunset.

It is the well known fact that glycogen is an important source of energy and therefore of activity. In the case of a mouce, HOLMQUIST ('31) says that glycogen in a liver decreases when a mouce moves about actively, and increases when it rests. MORI agrees with this result, using pearl oyster *Pinctada martensi* ('48-2) and sea-pen *Cavernularia obesa* ('50). But with the freshwater snail *Semisulcospira libertina*, the maximum quantity of glycogen is observed at 5 hours after the beginning of the daily routine movement when the highest activity is observed, and then it decreases

2) The amount of glycogen per unit weight of fresh materials of the fish, during a month's hunger, decreases to about a half of that of the well fed fish.

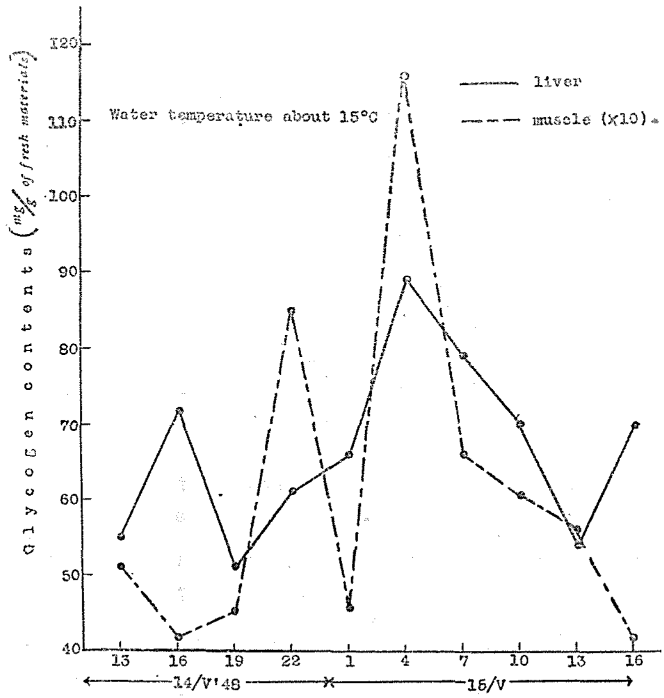


Fig. 3 Periodic changes in glycogen contents of livers and muscles (the mean value of 5 male fishes)

as the activity grows weak (MORI, '46). In this case, the time when glycogen is accumulated to the maximum quantity is observed closer to the time when the activity reaches its maximum as compared with the cases of a mouce or a pearl oyster. The present result with well fed loach seems to show the intermediate condition, that is to say, the greatest quantity of glycogen, through the whole course of the daily periodic activity, is found at the end of the activity phase at night. After all, although there is a distinct relation between periodicity in activity and change in glycogen, the details of the relation are proved to be different in various animals.

IV. Feeding and the subsequent increases of activity and glycogen contents

When the loach is kept in hunger, its liver becomes smaller and its glycogen contents decrease, and at the same time the daily periodic movement gradually falls off. If we supply food to the loach in such a condition, its activity begins to grow more and more lively after a certain period. Is there any relation, in this case, between the glycogen quantity and the activity of the loach ?

Several male fishes were kept in hunger, and the recording of the activity and the glycogen analysis were made as mentioned above, during the periods of May and October of 1947. One of the results we obtained is shown in Figure 4.

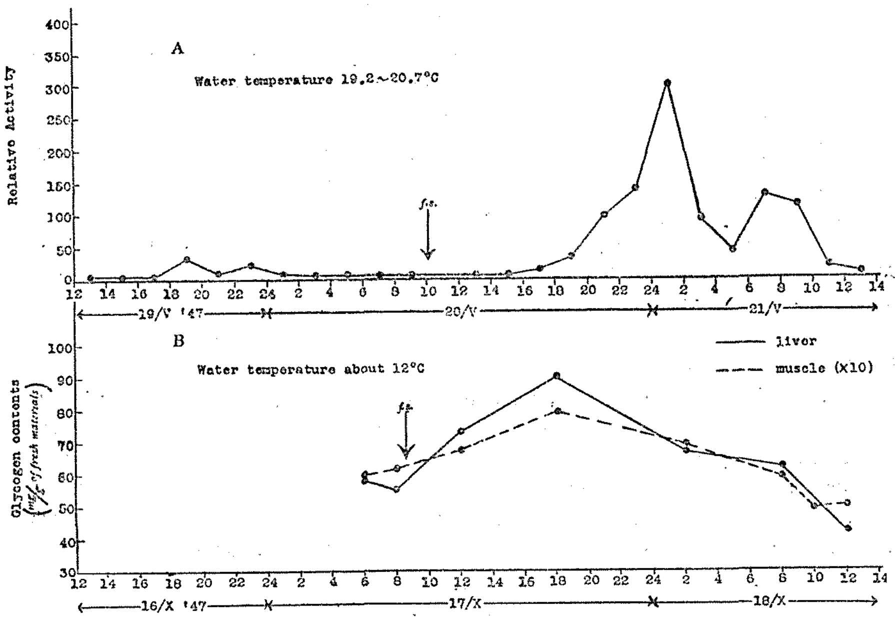


Fig. 4 Feeding and the subsequent increases of activity and glycogen contents
A: An instance of the change of activity shown before and after feeding (7 fiishes male and female were used).
B: An instance of the change of glycogen contents in a liver shown after feeding (male fishes were used).
f.s.: The time when food was supplied.

We know from this Figure and from the similar experiments that;
(a) Hungered fishes usually begin to move livelily just 10 hours after taking food.
(b) The glycogen content in a liver begins to increase instantly after taking food and usually reaches the maximum about 10 hours later.
(c) Thus, the changes in activity and in glycogen contents well accord with each other, and so we may conclude that about 10 hours after the hungered animal is fed, when nutrients are penetrated all over the body, it begins to move about livelily.

We must note here that there is a contradiction between the result mentioned in the previous chapter and the result described in this chapter. At the former case, i. e. at the case of well fed normal animals, the greatest quantity of glycogen was observed at the end of the activity phase; but at the latter case, i. e. when hungered animals were supplied with food, the activity began when glycogen was accumulated to a fair amount in livers. The cause of this contradiction is not clear, but the difference in antecedents may be, at least partly, responsible for.

V. Summary

1. The Japanese loach is a nocturnal fish, having 2 peaks of activity at night, the one after the sunset and the other after the midnight. A hungered fish, however, shows only faint, scarcely periodic activity.

2. The change of glycogen quantity in a liver shows 2 peaks a day, that is, before the sunset and the sunrise, the latter being greater. The change of glycogen quantity in a muscle also shows 2 peaks a day, namely, before and after the midnight, the latter being far greater. It is obvious from these facts that the intimate relation exists between the glycogen in a body and the periodic activity. When the fish is starved, the daily periodicity of glycogen quantity becomes obscure in a liver, but in a muscle the periodicity seems to be recognizable.

3 The hungered fishes, on the one hand, usually begin to move livelily just 10 hours after they are fed. The glycogen contents in livers, on the other hand, begin to increase instantly after the loaches take food and usually reach the maximum about 10 hours later. It may be said from these facts that about 10 hours after the hungered animal is fed, when nutrients are penetrated all over the body, it begins to move about livelily.

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