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Harmony Between Behavior Rhythm and Environmental Rhythm

By

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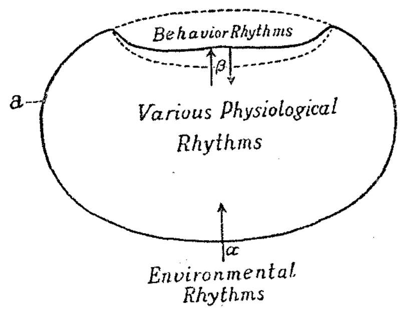
1. There are many kinds of rhythmic phenomena in animal behavior and they play important roles in life. In this paper I intend to propose an opinion on the relation between *daily rhythmic activities* and *environment.* Daily rhythmic activities are influenced by several environmental factors, but it may be reasonable to suppose that the real inducing factors must be those showing daily rhythmic changes which repeat regularly, and therefore light will be the most important factor, and temperature may come next. Other factors than light and temperature may not be of much consequence, and even if they appear to be influential their actions can usually be analysed under the combined effects of light and temperature. The biotic factors, although they may sometimes appear to have important roles, generally have no decisive effect in evoking daily rhythmic activity (Mori, 1945 — 2, 1946).

2. Then, what kind of modification would occur in rhythmic behaviors when animals are kept under certain constant environmental conditions? Many investigators have attempted to solve this question, and now we know that certain rhythmic phases are easily disturbed (e. g. the expansion and contraction rhythm of the sea-anemone *Cymbactis actinostroides*; Mori, 1943), while some persist in their original rhythms for a week or so till they become irregular (e. g. the general activity rhythm of the sea-cucumber *Holothuria vitiens*; Yamanouti, 1939), and others maintain their rhythmic lives as long as 100 days or more (e. g. the expansion and contraction rhythm of the sea-pen *Cavernularia obesa*; Mori, 1947 — 1). As an extraordinary case, the young Japanese dancing mouse, born in a dark room and kept there, is said to have persisted in its daily rhythmic activity (Wolf, 1930). It may be clear from these instances that there are various

degrees of persistency in the rhythmic activities of animals (Mori, 1945 — 2). Although Park (1840) has distinguished two types in daily rhythmic activities, i. e. exogenous and endogenous, there exist numerous transitory ones between these.

3. A daily rhythmic activity, in my opinion, is an external manifestation of various physiological rhythms existing in the body, and the animals showing more or less persistent rhythmic activity under constant external conditions are those capable of maintaining internal physiological rhythms by their own power for some days or months or even years. I have already presented a model to demonstrate that these physiological rhythms seem to occur as a result of the cyclic repetition of complex chemical reactions and the transtitions of equilibriums (Mori, 1947 — 2). Many physiological phenomena correlating with the metabolism, such as O_2 consumption, consumption and accumulation of glycogen, changes of $H^{\cdot}$ concentration in the body fluid or cell sap (Mori, 1944 — 2, 1945 — 1), etc., are playing important roles in this connection.

4. I should like to present here a hypothetical schema (Text-figure) to explain the relations mentioned above, and discuss it with reference to the history of animal species. When an organic construction of a species is established, and as it becomes more intimately



Text-figure: Schema showing the relation between environmental rhythms and behavior rhythms. a: animal body. arrows: the courses through which various energies are transferred. Various physiological rhythms occur on the bases of transitions of chemical equilibriums (modified from Mori, 1947 — 2).

accustomed to its definite environment, the same mode of thythmic life is repeated day after day. At the earlier stage, the activity is regulated by environmental factors only ; and the physiological as well as the behavior rhythms are evoked only by the supply of external rhythmic energies through the *α* route in the figure. In such a stage, no automatic cyclic linkage is recognized between the behavior rhythm and the chemical reactions taking place in the body. This stage may correspond to that of the exogenous activity. In the next stage, the animal becomes better accustomed to its rhythmic life pattern, and the relations between the physiological rhythms and behavior rhythms become more intimate and firmer. In this condition, one change in some biochemical reaction complex will automatically induce other changes, and the animal can maintain its original rhythmic life for some period. But the rhythmic activity supported by the internal rhythmic supply of energy through the β route alone will gradually become fainter, if the external supply of energies through the α route is excluded. This stage may correspon l to the endogenous activity. From this view-point, it seems natural that many transitory activity patterns are recognized between endogenous and exogenous modes.

5. If an animal continues its routine rhythmic life, the energy of intern al cyclic changes which bring the transition of physiological and behavior rhythms will grow greater. The degree of the establishment of automatism may be given by $p/e = i$, where p is the rhythmic energy supplied from internal cyclic changes and e is the rhythmic energy from environment. For an animal species, the phases of the rhythmic activity, controlled respectively by e and p, may be nearly consistent, and the value of i may also be practically constant at a certain age of the animal. In other words e and p seem to be acting in complete harmony. The value of i will grow larger with the age of individuals, and perhaps also with the advance on their specific history, and this fact means the decrease of plasticity to sudden environmental changes. Here will be given a metaphorical explanation, taking the vacuum tube oscillator as an example, on the relation between the changes in external rhythmic energy, due to rhythmic enviornmental changes, and the internal rhythmic energy, due to cyclic physiological rhythm, which causes the behavior rhythm. When $p = 0$, or when there is no automatic physiological rhythm, the condition may be compared with the oscillatory arrangement which is not set in motion. Increasing the value of p has the same significance as the gradual completion of the oscillatory arrangements, which may be effected by equipping such mechanisms as various kinds of vacuum tubes, resistances, etc. In a simply equipped mechanism, the oscillation damps quickly if no external rhythmic energy is supplied, as will be seen in Hertz's oscillator. But in a better equipped oscillator, such as the vacuum tube oscillator the oscillation does not damp for a considerable

time even when the external supply of rhythmic energy is discontinued. Of course, as the energy of oscillator itself is supplied continuously from the electric cell, the energy of organic activity must be supplied continuously from the nourishment taken from outside. As even those oscillators, which have complete self-oscillatory mechanisms cannot maintain their original oscillatory rhythms when influenced by strong external energies with different rhythmic phases, so even those animals which have well-established endogenous activity patterns fail to persist in their original rhythmic activities under the influence of external factors with rhythmic phases modified experimentally beyond certain ranges tolerable to them (Mori, 1944 — 1, 1945 — 2).

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Leterature

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