Reports and Letters

Latent Learning in Earthworms

It has been suggested that any attempt to explain the complex kind of purposive action made possible by a highly developed central nervous system may be premature as long as we do not possess an adequate biological theory of the comparatively simpler kinds of purposive functioning (*1*). If, therefore, our purpose lies in understanding the functional relationship that exists between a complex nervous system and its environment, we must start by obtaining information about the behavior of nervous systems belonging to simpler organisms (*2*). The present study considered the problem of learning for a comparatively "simple" animal, the earthworm.

We selected the earthworm because it is one of the lowest invertebrates in which modifiability has been demonstrated and also to allow for subsequent experimentation attempting to show that higher nervous centers are necessary for the formation of cognitive maps—that is, without the supra-esophageal ganglion, latent learning is not possible, but not in the simpler situation of the reinforced type. In addition, we agree with those workers who have emphasized the importance of analytic studies of learning in very different animal types, for these investigations should reward us with important evidence and theoretical insight.

Investigations on the behavior of the earthworm date back to the classic paper of Darwin (*3*), who went so far as to ascribe "some degree of intelligence" to it. The studies of Yerkes (*4*) and von Heck (*5*) showed that earthworms are capable of learning a simple T-maze and that removal of the first five segments (cephalic ganglia) will not result in a loss of habit until the new segments have been regenerated. The work of Swartz (*6*) has shown that the behavior of the earthworm in a T-maze is random until training is started. Robinson (*7*) and Schmidt (*8*) have recently investigated learning in the same animal, with a view toward proving and disproving, respectively, the existence of a two-factor theory of learning.

The specific problem we investigated was that of latent learning. Our hypothesis was that the animals confined to the maze for 20 hours prior to training with reinforcement would reach the criterion of seven successive correct responses (or more) out of ten trials in fewer runs than the animals that had had no previous maze experience.

Six earthworms (*Lumbricus terrestris* L.) were used, three in the latent (L) group and three in the reinforced (R) group. The T-maze was constructed as follows: The arms were constructed of glass tubing 25.4 cm long and 2 cm in diameter. The vertical arm was constructed so that it could fit into the horizontal arm, but it was detached therefrom. The position of the junction between the two arms was such that the horizontal arm was divided into a left arm of 10.1 cm and a right arm of 15.3 cm. These arms represented the negative and positive goals, respectively. At the end of the left arm (negative goal) very rough sandpaper was placed. This was followed by electrodes that delivered a shock of 1 volt. At the end of the right arm (positive goal) was a glass beaker filled with moist earth and moss. The beaker was covered with paper in order to reduce the light. The floor of the maze was lined with moist blotting paper, which was changed frequently to prevent tracking.

The following procedure was used. Group 1 (R): the animals were run with positive and negative reinforcement. Group 2 (L): the animals were allowed to run in a closed T-maze for a cumulative period of 20 hours. Negative or positive reinforcements were used during this period. At the end of this time, the animals were removed from the maze and run with positive and negative reinforcement. A correct choice was defined as turning to the right and going halfway down the right arm. The animals were run five times a day, when possible. Time between trials varied from 50 seconds to 20 minutes. A flashlight and a small camel's hair paint brush were used whenever necessary to start the animals moving when they halted for any length of time. After they had completed their runs in the maze, the animals were put in large Petri dishes, which were then put in the refrigerator, since the animals seemed to thrive best under these conditions.

The number of trials necessary for the animals in the R group to reach the required criterion was 37, 45, and 47, respectively. For the animals in the L group, the number of trials was 21, 22, and 23, respectively. The t test was employed to test the hypothesis that the mean number of trials required for learning by the R and L groups are equal against the alternative that the means are unequal. The t test substantiated (at the 0.01 confidence level) our initial hypothesis that the L group would learn more rapidly than the R group. An analysis of the complete data was done, utilizing the theory of stochastic processes. A Markov chain model was developed; its applicability to learning experiments has been discussed (*9*).

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References and Notes

1. F. A. Hayek, *The Sensory Order* (Univ. of Chicago Press, Chicago, 1952).
2. I have also considered the problem of using the ameba in T-maze situations and studying the effects of learning, and retention if any, in its progeny. However, this problem was temporarily abandoned because of experimental difficulties.
3. C. Darwin, *On the Formation of Vegetable Mould through the Action of Worms, with Observations on Their Habits* (Appleton, New York, 1898).
4. R. M. Yerkes, *J. Animal Behavior* **2**, 332 (1912).
5. L. von Heck, *Lotos* **68**, 168 (1920).
6. R. Swartz, *J. Comp. Psychol.* 9, 17 (1929).
7. J. S. Robinson, *J. Comp. Physiol. Psychol.* 46, 262 (1953).
8. H. Schmidt, *Science* 121, 341 (1955).
9. R. P. Bharucha, unpublished master's thesis, Illinois Institute of Technology, 1953.
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Fresh-water Sawfishes and Sharks in Netherlands New Guinea

A short notice on the occurrence of sharks and sawfishes in Lake Sentani, Netherlands New Guinea, has recently been published [*Science* **121**, 759 (1955)]; about the same remarks can be found in the 18 February 1955 issue of the Australian newspaper *Daily Telegraph*. Because the data, which are said to be provided by H. Van Pel, fisheries officer for the South Pacific Commission, contain several errors, a rectification in this place seems advisable.

Lake Sentani is situated in the extreme northeastern part of Netherlands New Guinea; the eastern shore is within 10 miles southwest of Hollandia at an altitude of only about 250 feet above sea level. There is an effluent river of length about 40 miles that is, according to local (and rather unreliable) information, hardly passable in its upper reaches even for native proas (canoes). According to