REINFORCEMENT CONCEPT IN INVESTIGATIONS
ON SIMPLE NERVOUS SYSTEMS

P. M. Balaban

An analysis of the applicability of the concept of reinforcement to the studies of learning in simple nervous systems of invertebrates is made. Analysis of the literature data and my own results suggests that reinforcement cannot be regarded as an independent behavioral phenomenon. A description of reinforcement as a state of the nervous system which precedes long-term changes of behavior is given. Using the example of aversive conditioning to food in gastropod snails it is shown that a state of the network that can be correlated with the state of reinforcement can be elicited in this simple nervous system by activation of serotonergic pedal cells modulating avoidance behavior of the animal. The conclusion is made that with certain limitations the reinforcement concept can be used in studies on simple nervous systems.

The concept of reinforcement has been widely used in studies of learning and memory mechanisms during the last decades not only at the behavioral level, but also in model systems: brain slices, invertebrate isolated nervous systems, and synaptically connected neurons in vitro and in vivo. The terminology elaborated for animal behavior is mostly used in these studies. The present paper is aimed at an analysis of the limitations and applicability of the behavioral concept of reinforcement to neurophysiological experiments in model systems.

Reinforcement in Learning Theories

Analysis of abundant literature concerning theories of learning in psychological terminology, i.e., describing the behavioral events, allows one to find in each approach common ideas and to relate them to the contemporary concept of reinforcement.

Historically, the term reinforcement has had many differing meanings. Spencer's theory of learning [10] was the first systematic attempt to give explanations of the differential strengthening of behavioral pattern. His theory implied as obvious that an organism would tend to repeat actions that brought pleasure and desist from those which brought pain. In cases when pleasure accompanied actions beneficial for survival, or pain accompanied injurious actions, the animal got a preferential position for natural selection. Spencer's theory was the first which implied the existence of reinforcement necessary for differential change in behavior.

The term "reinforcement" was introduced in the psychophysiological arena in the laboratory of I. P. Pavlov, and appeared in the world literature after publication in 1927 of a translation of his "Twenty Years of Experience" first published in Russian in 1923 [9]. Reinforcement in this theory of learning is directly connected with unconditioned stimulus which exerts the "reinforcing action" (Fig. 1). As was noted in a paper by Pavlov's student Asratyan [2] devoted to the problems of reinforcement, in Pavlov's publications there is no special work analyzing reinforcement as a concept, which suggests that Pavlov never regarded this problem as an independent one.

In the "Law of Effect" formulated by Thorndike [13] it is clearly stated that the nervous system is so constructed as to lead to the strengthening of those connections which have been active just prior to satisfying events, and to the weakening
of those connections which have been active prior to annoying events. This change of effectiveness of stimulus-response (S-R) connections implies existence of some sort of nervous process influencing the S-R connections and depending on the behavioral effect of contingency of stimuli.

In the studies by C. L. Hull [7], which are to some extent a continuation of Thorndike’s "Law of Effect," the concept of biological need and its associated drive were introduced. Drive reduction, increasing the probability of S-R association, has the properties of reinforcement in this theory (Fig. 1). B. F. Skinner [12] introduced a concept of events which may serve as "reinforcers," and which are not connected exclusively with stimulus or reaction (Fig. 1). A concept of "emitted operants" which can be brought under the control of a stimulus by arranging for the emission and reinforcement of the operant in the presence of the stimulus completed his description of behavior.

It is essential to note that in all the mentioned theories of learning there is a common property: Stimulus, response, and motivation are mentioned in all of them in somewhat differing contexts, but involvement in learning of these phenomena is acknowledged. Basing on the experiments, different authors assign the reinforcing properties either to stimulus or reaction or motivation, and in all cases the argumentation is strong and valid. It suggests two possibilities: Only one of the authors is right, which is improbable, or that all of them are right, which means that reinforcement cannot be linked only to one of the mentioned phenomena.

Our next question is: "What is reinforcement? Is it an independent behaviorally described phenomenon or is it a state of the organism which can be elicited by different ways?"

**Reinforcement: Independent Phenomenon or State of the Organism?**

As was noted, in the publications of I. P. Pavlov, reinforcement was never considered as an independent phenomenon [2, 9] in spite of the fact that its importance was mentioned in each paper. A prominent Pavlov student, P. K. Anokhin, also stressed the role of reinforcement [1], but never regarded it independently in his papers. A brilliant analysis of reinforcement as a concept was made in the book "Reinforcement and Behavior" by E. Walker [14]. He compared the influence of reinforcement on studies of learning with 'The One Ring' from Tolkien's "The Lord of the Rings." The possessor of the One...