

leased by a stimulus that does not directly drive the reflex. These three modes of producing a behavioral response involve different combinations of the same population of motor elements. In the simple withdrawal reflex all of the known motor cells are activated, whereas in the spontaneous and triggered withdrawal one subset of these cells is activated and the other is inhibited. Thus, as a result of multiple inputs, the different members of the same population of motor cells can be switched between either a simple reflex or a more complex response that shares certain features with innate or instinctive behaviors (14).

In view of its advantages for cellular neurophysiological studies this preparation may prove useful for analyzing the neuronal mechanisms of learning. Initial experiments indicate that the behavioral reflex responses can be modified to show simple learning, such as quasi conditioning (sensitization), habituation, and dishabituation (15). Because the withdrawal response can occur either reflexly or spontaneously, it may also prove possible to study more complex behavioral modifications using either classical or operant conditioning paradigms.

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12. The dorsal surface of left caudal quarter ganglion in which these motoneurons are

located consists of cells L7 and L11 and three clusters of cells (LB, LC, and LD) each of which consists of cells having a number of common properties. The most prominent members of the LB and LC clusters were previously designated L8 and L9, respectively, but it was otherwise impossible to distinguish between the cells within the clusters (6). On the basis of motor function these groups can now be further subdivided. Most cells in group LB have no grossly observable motor effects on the external organs of the mantle cavity. A few LB cells, including L8, produce small and inconstant movements but these effects are so small that these cells have not been included as motoneurons in our analysis. In addition to L9 (now called L9-1) the LC group has a second prominent cell which we call L9-2 which also produces motor movement. Two cells of the LD cluster, LD-G and LD-S, produce motor effects but other LD cells appear not to do so. The five

motor cells described probably constitute a major component of the motor outflow of the withdrawal responses but some motor cells have almost certainly been missed. Although the four gill motoneurons produce different types of gill contractions, these differences will not be described in the present report.
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Learning Sets in an Invertebrate

Abstract. Eight isopods, *Porcellio scaber*, were trained with water reinforcement to turn in a T-maze to criterion of correct responses. They were then tested through nine reversals of the turning response. An analysis of variance indicated that mean errors to criterion declined significantly over reversals ($F = 4.78$, $d.f. = 9/63$, $P < .001$).

In the study of learning capacities of various species, the phenomenon of learning sets (1) has seemed to separate vertebrates from the invertebrates. Attempts to demonstrate learning sets in invertebrates, other than the highly specialized octopus (2), have been unsuccessful. Thompson (3) found that although the isopod *Armadillidium vulgare* could learn to reverse a position response in a T-maze, succeeding reversals produced no significant decrement in mean trials or errors to criterion. Harless (4) obtained similar results with *Porcellio scaber*. Where Thompson used the application of an electric shock contingent on a wrong turn in the T-maze, Harless made the onset of a bright light contingent on a wrong turn in a Y-maze. Both investigators report that while certain individual data seemed to show a reduction in errors over reversals, the group data failed to show any significant statistical evidence of a learning set phenomenon.

Pietsch (5) studied this phenomenon

in *P. scaber* but used a different reinforcement technique. Her animals began running a T-maze illuminated with a bright light previously demonstrated as aversive. When an animal turned in the correct direction the light was removed. The animals were able to learn 8 reversals, and mean errors appeared to decline over reversals; however, statistical analysis failed to demonstrate the significance of the trend.

These studies involved aversive stimulation. Thompson and Harless used avoidance conditioning, and Pietsch used escape conditioning. However, it is appropriate to investigate other reinforcement techniques before concluding that these animals are unable to demonstrate learning sets. The fact that lower vertebrates such as newts and terrapins can demonstrate learning sets (6), as well as the efficiency with which some invertebrates spatially orient themselves while foraging for food, calls for further work (7). We have investigated learning sets in *P.*

Table 1. Number of errors to criterion for each subject.

Subject	Reversal									
	0	1	2	3	4	5	6	7	8	9
1	20	29	27	11	16	23	9	14	6	1
2	29	48	7	15	12	7	11	7	8	5
3	38	23	29	33	27	29	15	6	15	23
4	1	7	21	15	10	1	19	6	11	1
5	38	23	9	11	7	5	1	1	0	16
6	17	23	20	9	16	14	14	17	15	14
7	21	15	15	9	16	20	1	3	7	7
8	56	21	21	11	30	12	19	14	7	2
$\bar{X}$	27.5	23.6	18.6	14.3	16.8	13.9	11.1	8.5	8.6	8.6

scaber with a technique of positive reinforcement where the animals were given access to water for a correct turn in a T-maze (8).

Eight *P. scaber* were given ten trials per day spaced approximately 20 minutes apart, in a wood T-maze. The arms and stem were 5 cm, internal diameter 0.8 cm, and height 1.3 cm. The floors of both arms were covered with a strip of paper towel (5 by 0.8 cm). Throughout the experiment the maze was kept in a styrofoam chamber (46 by 23 by 31 cm) that contained a heating element, a pan of water, and an Airguide thermometer and hygrometer. The chamber had a top window for viewing and an arm hole in each end to permit access. Conditions in the chamber were kept constant at approximately 32.2°C and 30 percent relative humidity. The chamber was kept in normal room light with care taken to see that no differential shadows were cast on the maze. The subjects were kept in individual environments containing soil, leaves, and a moist sponge, except for the time in the chamber.

Daily sessions began with water deprivation; animals were placed in the chamber for 4 hours in an empty paper cup. They were then given ten trials in the T-maze; a subject was placed at the entrance to the maze and allowed to proceed to the choice point and to turn in either direction. Immediately after a turn the subject was blocked in the arm for 15 seconds and then returned to the paper cup to await the next trial. At the end of ten trials the subjects were returned to their individual environments outside the chamber until the next day's session.

The first ten trials were used to determine any turning preference. A majority of turns in one direction was designated as preference, and on initial training a turn in that direction was counted as an error. A turn in the opposite direction was counted as a correct turn. Subsequently and throughout the experiment, when a correct turn was made and the subject was blocked, one drop of water was applied to the paper towel on the floor of the maze arm. The water spread quickly over the entire towel, permitting absorption by the animal. The subject was then removed, towels were removed, and the maze floor wiped dry and further dried with an electric hair dryer held over the maze for approximately 30 seconds. If an error was made no water accompanied the blocking, and the drying procedures were not used. The subjects were tested until a

criterion of nine correct turns out of ten consecutive trials was met. When criterion was met the correct turn direction was reversed. That is, the former error turn became the correct turn, and the former correct turn became the error turn. The animals were tested to criterion, and the correct direction was reversed again. This procedure continued for nine reversals (Table 1).

The mean errors to criterion showed a steady decline. An analysis of variance indicates that this decline is highly significant ($F = 4.78$, d.f. = 9/63, $P < .001$). This indicates formation of learning sets in these subjects. It would seem that invertebrates can do this with reasonable efficiency.

In the study of learning capacities of various invertebrate species, it may be particularly important to manipulate variables most relevant to their modes of adjustment. For example, it is unlikely that many invertebrates encounter electric shock in their environment. It is also unlikely that such stimuli played any great role in their phylogeny. Hence the effect of such stimuli on behavior may be too disruptive to allow demonstration of full adjustment capacities. In *P. scaber* dessication and subsequent response-contingent access to water represent a common mode of adjustment to a common environmental event. The similarity of these events to procedures of this experiment may offer a reason why this study was successful in demonstrating learning sets.

Experimental techniques making use of a positive reinforcer are usually associated with a concomitant deprivation procedure. This is more involved than the simple administration or withdrawal of aversive stimulation. Deprivation parameters must be investigated and reliable standards derived. This is particularly difficult with some of the lower species, yet its utility is clearly indicated here. The 4-hour dessication used in our experiment was derived from pilot work. Six-hour periods of lack of access to water at 32.2°C and 30 percent relative humidity seriously impaired the ability of *P. scaber* to run ten trials in a T-maze. Animals not having at least 2 hours of this dessication procedure showed pronounced inferiority at learning an initial position response.

The learning capacities of many species, especially invertebrates, have yet to be adequately delineated. We have attempted to show the fruitfulness of developing reinforcement techniques that are more relevant to the particular ecology of the species studied. When

this is accomplished it is possible and even likely that phenomena such as learning sets can be demonstrated in many invertebrate species other than the one studied here.

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Comparison of the Effects of Marihuana and Alcohol on Simulated Driving Performance

Abstract. *The effects of marihuana, alcohol, and no treatment on simulated driving performance were determined for experienced marihuana smokers. Subjects experiencing a "social marihuana high" accumulated significantly more speedometer errors than when under control conditions, whereas there were no significant differences in accelerator, brake, signal, steering, and total errors. The same subjects intoxicated from alcohol accumulated significantly more accelerator, brake, signal, speedometer, and total errors than under normal conditions, whereas there was no significant difference in steering errors. Impairment in simulated driving performance does not seem to be a function of increased marihuana dosage or inexperience with the drug.*

We have determined the effect of a "normal social marihuana high" on simulated driving performance among experienced marihuana smokers. We compared the degree of driving impairment due to smoking marihuana to the effect on driving of a recognized standard—that is, legally defined intoxication at the presumptive limit of 0.10 percent alcohol concentration in the blood. This study focused atten-