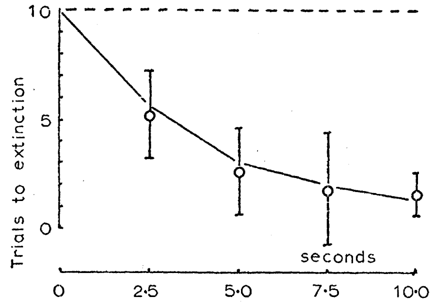

Fig. 1. The average effect of lever withdrawal on five animals. The solid line shows the prediction from Deutsch's hypothesis. The dotted line shows the prediction from the hypothesis that extinction is a function of the number of unreinforced trials. The circles are the experimentally observed effects of lever withdrawal.

reinforcement pathways. Hence the electrical stimulus will reinforce a present lever press and simultaneously motivate future ones. On this hypothesis the habits are resistant to satiation because each stimulus increases rather than decreases the drive state of the animal, while the fast extinction is due to the decay of the drive state when the electrical stimulus is switched off.

It seemed that the simplest way to test Deutsch's hypothesis lay in its prediction that extinction should be a simple function of time since the last electrical stimulus and would be independent of the number of unreinforced lever presses occurring in that time. This prediction is in marked contrast to extinction of the more usual kinds of lever-pressing habits which are very little affected by a time interval between training and extinction (*3*) and which extinguish more quickly with massed rather than spaced trials (*4*).

Our first experiment was simply to remove the rats from the lever by hand. At first they struggled to return to the lever, but after about 20 to 30 seconds they ceased to struggle and when released showed no inclination to return to the lever.

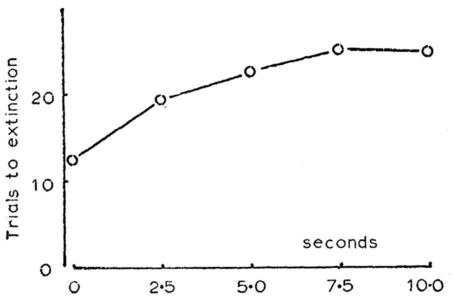

Fig. 2. The number of lever presses to extinction increases as a function of the duration of an increment in stimulus intensity.

In a second experiment, we attempted to measure the speed of extinction a little more precisely. We used six male Sprague-Dawley animals which had been used in a previous experiment (*5*). After further training we compared their extinction under two conditions, one of normal extinction and one in which the lever was removed from the box for 7 seconds before the extinction trials started. Our prediction was that the number of lever presses to extinction under this condition would be the same as the number of lever presses occurring after 7 seconds of normal extinction, and that the animals would stop responding at the same time in both cases. The average figures for ten trials in each condition on six animals were 1.92 and 1.87 lever presses and 11.4 and 10.1 seconds.

In our third experiment we took five experimentally naive male albino rats of the Sprague-Dawley strain, three with tegmental electrodes and two with hypothalamic electrodes. They were trained to press the lever for a minimal electrical stimulus. We then compared their performance under normal extinction with extinction after the lever had been removed from the cage for 2.5, 5.0, 7.5, and 10.0 seconds immediately before the extinction trials. The conditions were given in a balanced order. For each animal we measured the number of lever presses during normal extinction which occurred more than 2.5, 5.0, 7.5, and 10.0 seconds after the electrical stimulus was switched off. These figures we treated as predictions of the number of lever presses to extinction after 2.5, 5.0, 7.5, and 10.0 seconds of lever withdrawal. The results are shown in Fig. 1. Again the data fit very well the hypothesis that extinction under these conditions is a simple function of time since the last electrical stimulus to the brain, and flatly contradict the alternative hypothesis that extinction is a function of the unreinforced lever presses.

Since the extinction curves plotted as in Fig. 1 can be considered to reflect the decay of some drive process, we attempted to get a comparable measure of the growth of the same process. To do this, we investigated in a single animal the effect of the duration of an increase in the stimulus intensity on the number of lever presses to extinction. Instead of removing the lever from the cage prior to the extinction trials, we now increased the intensity of the stimulus by 50 percent for intervals of 2.5, 5.0, 7.5, and 10.0 seconds, before starting the extinction trials. The results are shown in Fig. 2. The number of lever presses to extinction increases with the duration of the higher intensity of stimulation in a way which resembles the form of the decrease shown in Fig. 1.

A speedy cessation of a habit maintained by electrical stimulation of the lateral hypothalamus has been found by Wyrwicka *et al.* (*6*). In their experiment the habit was learned for a food reward and its subsequent evocation by stimulation of the lateral hypothalamus can only be attributed to a motivational effect of the stimulation. Also, in this case the food reward was still available so that the cessation of the habit can only be explained by a swift reduction of the hunger drive when the stimulation stops (*7*).

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9 April 1962

Transportation of Oyster Drills by Horseshoe "Crabs"

Abstract. Horseshoe "crabs" (*Limulus polyphemus*) collected in New Haven Harbor, Long Island Sound, had large numbers of oyster drills attached to them. Since these animals migrate long distances, they may be important distributors of oyster drills.

Attempts to protect shellfish beds from predaceous gastropods, *Eupleura caudata* and *Urosalpinx cinerea*, by removing the predators by mechanical (*1*) or chemical (*2*) methods may be only partially effective because these gastropods can reinvade the beds. For example, benthic arthropods may carry these gastropods back into cleared areas. The first record of phoresy of oyster drills on benthic arthropods was made by Federighi (*3*) while working in the lower James River, Virginia. He reported that *U. cinerea* may be carried considerable distances by hermit crabs, *Pagurus* sp. Later, Carriker (*1*) cited similar observations made by two workers in Barnegat Bay, New Jersey. Carriker also cited a personal communication by J. R. Nelson who saw a horseshoe "crab," *Limulus polyphemus*, transporting 140 gastropods. Neither species of gastropod nor locality, however, is mentioned.

On 13 October 1961, while dredging on an oyster bed at a depth of 18 feet in New Haven Harbor, Long Island Sound, we collected nearly 50 horseshoe "crabs." These were predominantly large animals that had the eroded, dark-colored carapaces characteristic of older adults. The majority had a large number of oyster drills attached to various parts of their bodies, mostly on the dorsal side of the carapace (Fig. 1). The largest number of drills found on a single individual was 765, of which 761 were *Eupleura caudata* and only four were *Urosalpinx cinerea*. On some parts of the "crabs" the drills were so numerous that they formed three or four layers. Inspection of the carapaces showed no evidence of boring activity by the drills, nor were the drills boring each other.

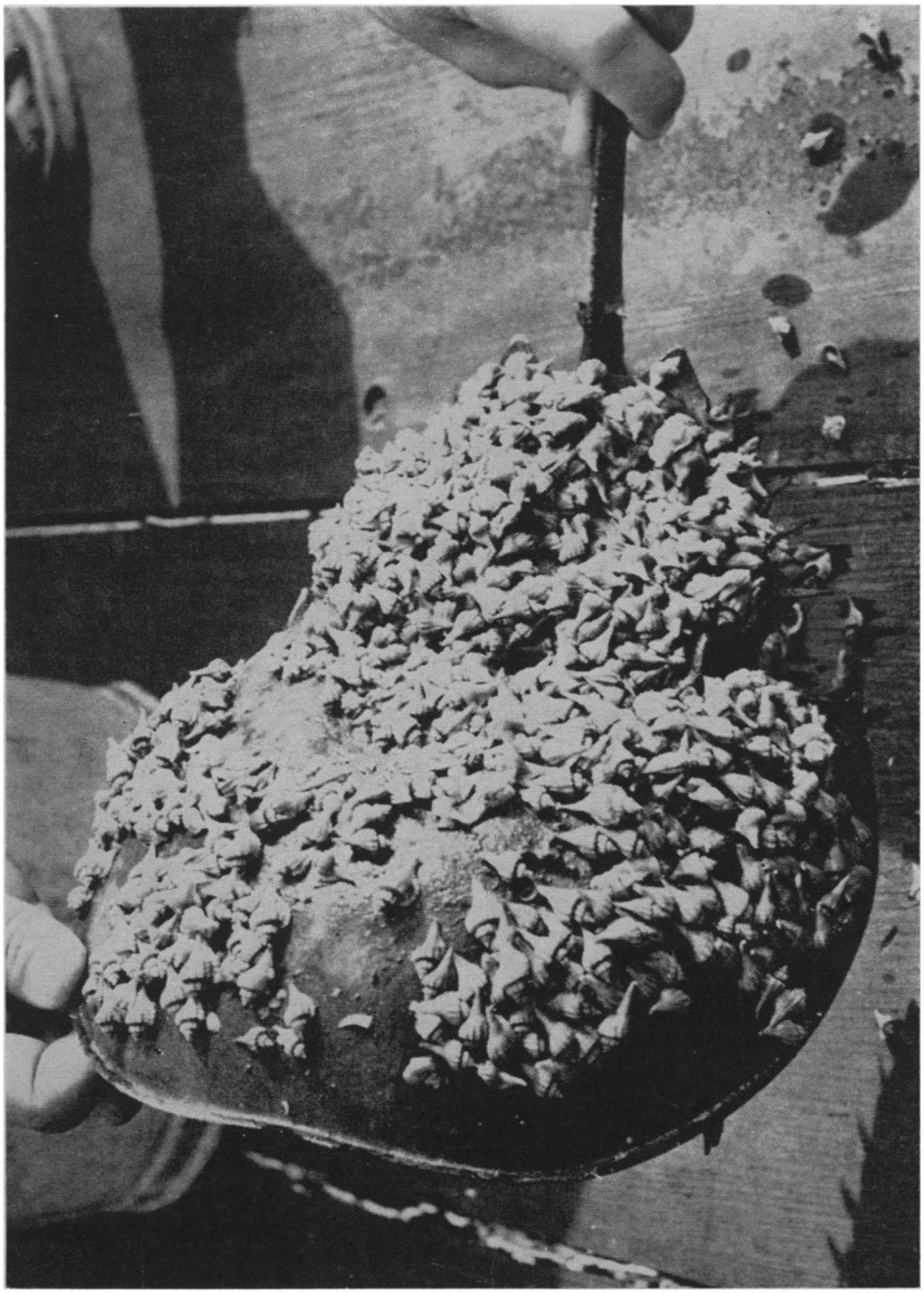

Fig. 1. Horseshoe "crab," *Limulus polyphemus*, with a large number of oyster drills, *Eupleura caudata* and *Urosalpinx cinerea*, attached. The "crab" was dredged from 18 feet of water in New Haven Harbor, Long Island Sound, Connecticut.

Originally the total number of drills attached to the horseshoe "crab" was undoubtedly even greater because many of them were knocked off or otherwise lost as the "crabs" were caught in the dredge and brought to the deck of the boat.

The bottom where the "crabs" were caught is muddy and harbors an extremely dense population of the duck clam, *Mulinia lateralis*. Probably the horseshoe "crabs," while feeding on the duck clams, scarcely had to move to find enough food, thus enabling the oyster drills to attach to their bodies. Perhaps these gastropods were attracted by juices exuding from the duck clams being crushed and eaten by the "crabs" or, in randomly moving about, they merely attached to the "crab" since it offered a hard surface in an area of soft mud.

Shuster (*4*, *5*) and Baptist, Smith, and Ropes (*6*) reported that adult horseshoe "crabs" migrate each year in the early summer from deeper water to the intertidal zone to spawn. They also found that adults travel for many miles along the shore (*4*, *6*). For example, Shuster (*4*), in Cape Cod Bay, Massachusetts, reported one "crab" 21 miles from the point of release. Considering the migratory habits of these animals, our observation in New Haven Harbor indicates that horseshoe "crabs" are an important distributor of oyster drills throughout the waters of Long Island Sound and, perhaps, beyond.

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