(Hardtack II), and the fission product levels in the Nevada Test Site herd were much higher in December 1957 and November 1958 than between tests (May 1958). The other two herds showed little change. This shows the effect of the relatively intense local fallout on the test site itself from smaller nuclear devices; this would be much more important for short-lived and intermediate-lived fission products than for the long-lived ones (such as Cs^{137} and Sr^{90}, the concentrations of which are not elevated in any of the three Nevada herds).

It is interesting that a new radioactivity, Zn^{65}, makes its first appearance in the November 1958 soft-tissue samples and remains present in the May 1959 samples. Zinc-65 is not a fission product, but is formed by neutron interaction on stable zinc. It has been detected in the general food supply (*9*), it is well absorbed from the gastrointestinal tract, and body retention is high (*10*). The amounts observed in the samples of liver and muscle were comparable to the Cs^{137} content.

External γ-ray dose and bone plutonium levels are trivial; the same was true of thyroid I^{131} levels with the exception of the Nevada Test Site herd soon after Hardtack II, when levels were of the order of the human maximum permissible level.

All reports from the Armed Forces Institute of Pathology indicate nothing significant from microscopic pathological examination. To date, no gross effects have been observed. The reproduction rate is normal, the animals are in a satisfactory state of nutrition, and there has been no increased incidence of any diseased condition.

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References and Notes

1. This work was performed under the auspices of the U.S. Atomic Energy Commission.
2. J. H. Harley, New York Operations Office, Atomic Energy Commission and Radiochemistry, Inc. (Sr^{90}); M. A. Van Dilla, Los Alamos Scientific Laboratory (γ-emitters); L. Van Middlesworth, University of Tennessee (I-131); K. H. Larsen, UCLA (Pu); Armed Forces Institute of Pathology (histology); G. R. Farmer, major (VC), and E. L. Johnson, captain (VC), stationed with U.S. Atomic Energy Commission, Las Vegas, Nevada (autopsy).
3. Annual Report, Lamont Geological Observatory, Columbia University (1 October 1958–30 September 1959).
4. W. H. Langham and E. C. Anderson, Hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, 86th Congress, vol. 2, pp. 1067–1169, 5–8 May 1959.
5. C. L. Comar, *ibid.*, pp. 1280–1298.
6. U.S. Atomic Energy Commission, New York Operations Office, Health and Safety Laboratory Reports HASL-10 (January 1958) and HASL-42 (1958).
7. A. Morgan and J. E. Wilkins, *Biochem. J.* **71**, 419 (1959).
8. J. L. Kulp, A. R. Schulert, E. J. Hodges, *Science* **129**, 1249 (1959).
9. M. A. Van Dilla, *ibid.* **131**, 659 (1960); G. K. Murthy, A. S. Goldin, J. E. Campbell, *ibid.* **130**, 1255 (1959).
10. M. A. Van Dilla and M. J. Engelke, *ibid.* **131**, 830 (1960).

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One-Trial Interhemispheric Transfer of a Learning Engram

Abstract. By using spreading depression to decorticate temporarily one hemisphere in rats, a learning trace was established in the opposite functional hemisphere. Spontaneous transfer of the engram from the *trained* hemisphere to the untrained hemisphere does not occur when both hemispheres are functional. If, however, the animal was allowed to make one reinforced response, complete transfer of the engram to the untrained hemisphere occurred.

We have been investigating (*1*) the use of spreading depression to decorticate temporarily one hemisphere and thereby to localize a conditioned performance to the other hemisphere as first described by Bureš (*2*). This approach derives from the work of Sperry and his co-workers (*3*), who showed a similar localization of learning engrams in the split-brain preparation. In our technique, cups were implanted chronically around small holes drilled through the skull of male albino rats, one over each hemisphere. The dura was left intact. Plungers fitted into the cups prevented dehydration of the brain. A small pledglet of cotton soaked with 25 percent potassium chloride was placed in the cup on one side to produce repetitive cycles of spreading depression restricted to that particular hemisphere. These spreading depressions inactivate the cortex for 3 to 4 hours (*2*).

The rats were given 1-hour daily sessions of operant training with one cortical hemisphere depressed. Under these conditions the functional cortex was exposed to bar-press conditioning under a continuous reinforcement schedule for food (*4*). In Fig. 1 the depressed cortical hemisphere is shown schematically, for each day, by cross-hatching.

On the first two days (Fig. 1), operant level scores were obtained, that is, measures of the animal's basal predisposition to respond without any training. On the 3rd and 4th days, the animal was reinforced for every response, and the increased rates indicate the animal had learned. The engram was shown to have been established in the cortex that remained functional during training, when this trained cortex was depressed by spreading depression. This is shown in Fig. 1, for spreading depression was produced in the *trained* cortex on day 5, and the animal's response rate declined to a basal level. It should be noted that the responses on day 5 were not reinforced, and thus they were obtained under extinction conditions. On day 6 the trained cortex was again functional, spreading depression was initiated on the untrained side, and the return of a higher rate of responding coinciding with the functional return of the trained cortex indicates that the engram was not impaired by the presence of spreading depression on the previous day.

The procedure of trying the trained side and the untrained side under conditions of reinforcement and extinction was carried out on the same animal over a number of days (Fig. 1). On days 5 and 9 the amount of responding of the animal under extinction with the trained cortex depressed is shown. As has been noted, this performance does not differ from the operant level performance prior to conditioning. These extinction scores are in contrast with the score obtained on day 11, when the trained cortex was functional during extinction. The presence of an engram is shown in that hemisphere by the retention of learning in extinction.

This use of extinction tests as a retention measure of learning shows more rigorously the presence of a unilateral engram than does Bureš's use of speed of learning scores, that is, the number of trials required to reach a criterion of conditioned performance. This operant technique is also flexible in terms

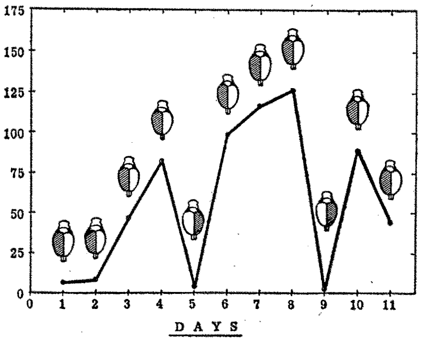

Fig. 1. Unilateral learning obtained by use of spreading depression as a technique of temporary decortication. The shading indicates the hemisphere depressed. The first two days give the operant level of responding before conditioning. Subsequent days show the increase in responding during training. On days 5, 9, and 11, responses are made during extinction. On days 5 and 9 the response level when the trained cortex is depressed is shown to be low as compared to day 11 when the trained cortex is functional.

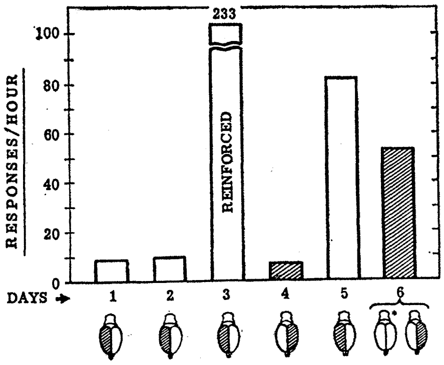

Fig. 2. Transfer of the learning engram to the untrained hemisphere. Days 1 and 2 give operant level, and day 3 shows the amount of responding made during training. The following days give the results of extinction tests. On day 4 the trained cortex is depressed, and day 5 shows the difference when the trained side is functional. On day 6 the animal was permitted to make one reinforced response with both hemispheres functional, and then 1 hour later the extinction test was given with the trained hemisphere depressed. The greater amount of responding indicates transfer has occurred after this single response.

of the kind of learning that can be established, and furthermore the presence or absence of a learning engram may be tested repeatedly over a number of days.

After recovering from spreading depression, the animal does not spontaneously transfer the engram to the other side, a point also noted by Bureš. Our testing procedure extended over a week or two, and, despite this prolonged period, transfer still did not occur. If, however, an animal with a unilateral engram was allowed to make one response and receive one reinforcement while both cortical hemispheres were functional, transfer of the engram to the previously untrained side occurred.

An example of an animal demonstrating such one-trial transfer is shown in Fig. 2. On the first two days operant level performance was recorded with one hemisphere depressed. On the 3rd day the learning of a conditioned performance is demonstrated by the 233 reinforced responses made during 1 hour of conditioning. An extinction test was given on day 4 with the trained cortex depressed. The animal here performed at operant level indicating that no "learning" had occurred in the untrained side. On the 5th day the animal was tested in extinction with the trained cortex functional, and retention of training was shown by the animal's making 83 responses without reinforcement. This is well above operant level. The animal was permitted one reinforced response with both hemispheres functional on day 6. One hour later the animal was again tested, this time with the *trained* cortex depressed. The extinction score of 56 responses indicates that transfer to the previously untrained side occurred and that one reinforcement was adequate to produce such transfer. The degree of success in training was tempered by the poor physical condition of the animals at the end of 2 weeks of continued elicitation of spreading depression, in view of which the positive evidence of one-trial transfer is additionally convincing. So far, 12 animals have shown unilateral learning, and an additional five have shown single-trial transfer.

These results are intriguing. The engram remains restricted to one hemisphere even though the neural connections for transfer are intact, and one single performance can result in transfer. It would seem that the animal does not transfer the engram without going through the actual behavior which is involved and that the "learning" of the engram by the untrained side takes place in an all-or-none fashion. This last point is of particular interest in connection with the work of Estes (*5*) whose recent psychological investigations led him, against his previous formulations, to think that learning is an all-or-none rather than an incremental process (*6*).

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References and Notes

1. I. S. Russell and S. Ochs, *Physiologist* **3**, 152 (1960).
2. J. Bureš, in *Conference on the Central Nervous System and Behavior* (2nd conf.), M. A. B. Brazier, Ed. (Josiah Macy, Jr. Foundation, New York, 1959).
3. R. W. Sperry, *J. Neurophysiol.* **22**, 78 (1959).
4. C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (Appleton-Century-Crofts, New York, 1957).
5. W. E. Estes, *Psychol. Rev.* **67**, 207 (1960).
6. A detailed report of this work is being prepared for presentation elsewhere. We are thankful to C. B. Ferster and T. Verhave for the loan of equipment at the beginning of this work, which was supported by the National Institutes of Health.

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Seasonal Evisceration in the Sea Cucumber, Parastichopus californicus (Stimpson)

Many species of sea cucumbers under rough handling will discard (eviscerate) their intestinal tracts and respiratory trees. For many years investigators at the Friday Harbor Laboratories of the University of Washington have noted occasional individuals of the large aspidochirote holothurian, *Parastichopus californicus* (Stimpson), which, when examined immediately after being dredged, lacked these organs. The general assumption has been that these animals probably were stimulated to eviscerate by the mauling experienced in the dredge.

Table 1. Presence or absence of intestine and respiratory trees in *Parastichopus californicus* collected at different seasons.

Date*	No. of animals	
	Complete viscera	Incomplete viscera†
2 Sept. 1959	12	0
28 Sept.	10	2
12 Oct.	8	4
26 Oct.	1	11
11 Nov.‡	0	25
10 Dec.‡	1	7
27 Dec.‡	1	0
22 Jan. 1960‡	17	0
3 and 5 Feb.	12	0
13 Feb.‡	5	0
4 March	12	0
18 March‡	23	0

* Also on 3 April, 30 April, 2 June, 4 July, and 3 August 1960, 12 specimens were collected, and all were found to have their viscera complete. † Intestine and respiratory trees lacking or in early stages of regeneration. ‡ Groups of specimens dredged from deeper water.

Some years ago in the late fall I collected a number of these animals from shallow water with a potato hook, brought them back to the laboratory in pails, and immediately opened them. The majority lacked the viscera mentioned above. The place of their collection was too shallow for dredging, and there was no reason to suspect that they had recently been handled by man, nor was there any evisceration after they were lifted from their habitat. Thus spontaneous evisceration, or at least evisceration in nature without stimulation caused by man's activities, was suspected.

In view of Bertolini's observations (*1*) on *Stichopus regalis* at Naples, which strongly suggests a seasonal evisceration in that species in late fall, the question arose as to whether or not *Parastichopus californicus* might not have a similar habit. Therefore, when an opportunity to spend another year at the Friday Harbor Laboratories (*2*) developed, plans were made for periodic collection of this animal from shallow water. As it appeared desirable to make all collections from the same locality, and because no readily accessible shallow-water area was found where the species occurred in very large numbers, each collection had to be limited in size.

Collections of 12 specimens each were made from a rowboat from low water to about 12 feet below that level with a long-handled potato hook. These animals were taken along the shore between the observation pier (48°-32.7′N, 123°00.4′W) and a cove about ½-mile north (48°33.3′N, 123°00.3′W), known locally as Fern Cove. A summary of the findings is given in Table I.