even under these conditions each pigeon responded to the stimulus trained as negative (S−) as if it were positive during tests of interocular transfer with the untrained eye alone open.

Thus evidence from anatomical, physiological, and behavioral sources argues against Cumming, Siegel, and Johnson's proposal that interhemispheric transfer of a monocularly learned pattern discrimination is literally "inter-ocular."

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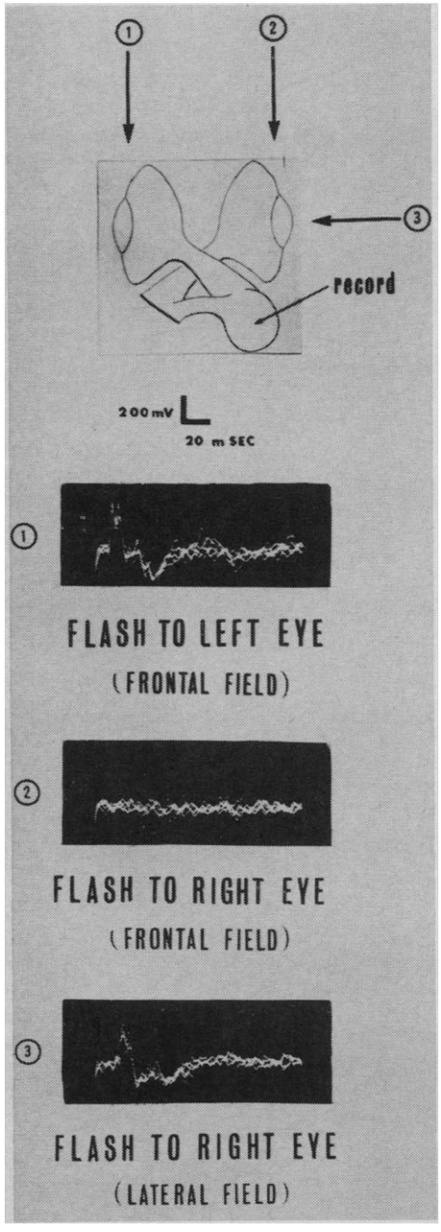
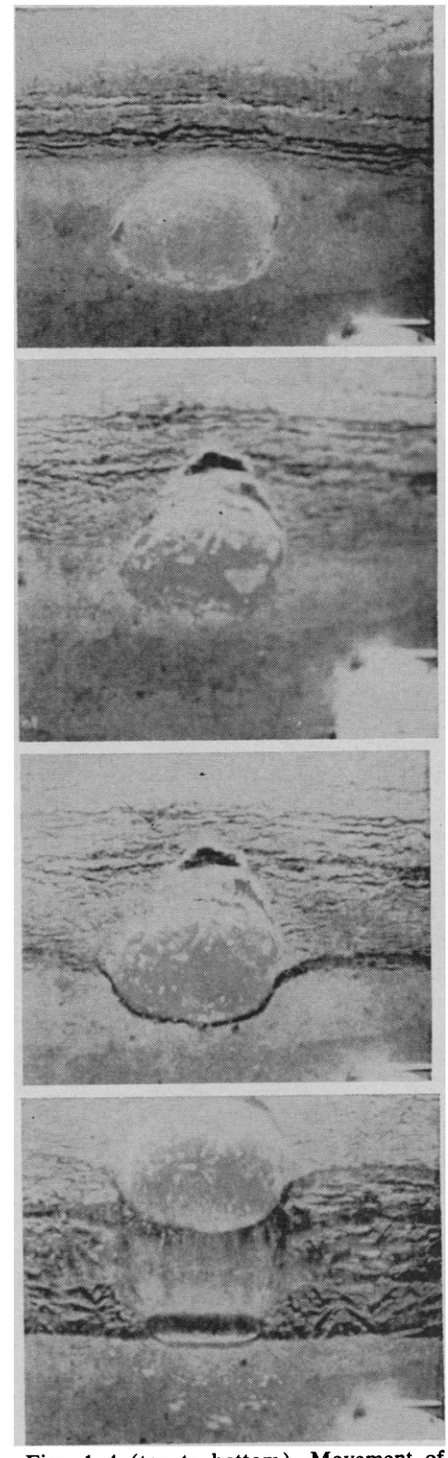


Fig. 2. Evoked potentials to flash recorded from the right optic tectum of the pigeon with a chronic ablation of the left optic tectum. Small, tungsten in glass electrodes (about 10 mμ tip) were used. The pigeon was anesthetized with nembutal (30 mg/kg). Flash stimuli were presented at 1 per second at maximum intensity through a black cone directed towards the orbit. The terminal aperture was 1.6 cm in diameter.

Stone Migration by Freezing of Soil

I have read with great interest D. R. Inglis's explanation of the uplifting of a large object such as a stone or fence post during freezing of soil [*Science* **148**, 1616 (1965)]. As early as 1958, using time-lapse color photography, I made observations of this phenomenon at the U.S. Army Arctic Construction and Frost Effects Laboratory, Waltham, Massachusetts (now merged with U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire). A 15-minute sound and color film entitled "Frost action in soils" was presented at the International Permafrost Conference at Purdue University in November 1963, and has been in continued circulation since. It has been shown at various gatherings of the American Society of Civil Engineers. It has also been shown in Japan and Sweden.

This film demonstrates, among other things, the upward movement of a stone and simulated piles within a silt soil by frost action, when freezing is from the top down in an open-system test. The narration accompanying the film is in very close agreement (with some exceptions) with the explanation set forth by Inglis. The film shows that adhesion of ice to the top of the stone was not the lifting force, although it might possibly be under certain conditions of object shape and relative position. What actually happened in the frost-susceptible material studied was that the soil directly over a stone was lifted above the stone, leaving a void. A stone rises only when the adfreeze force around it is greater than the forces holding it in place. The total movement of the stone from its initial position depends upon the heaving rate of the soil and the time required for freezing to penetrate down to a level below the cavity formed under the stone. In saturated non-frost-



Figs. 1–4 (top to bottom). Movement of a stone (actual size, about 3 cm diameter) in freezing soil. (The object partly visible at the lower right is a wrist watch.) Fig. 1: frost line approaching the top of the stone. Fig. 2 (about 30 hours later): the soil above the stone has heaved, leaving a void. Fig. 3 (about 12 hours later): the stone is being lifted by the grip of the frozen soil; there is now a void under the stone. Fig. 4 (about 79 hours later): the stone has moved up a considerable distance, and the cavity below has become slightly narrower and filled with water, which has frozen.

susceptible soils in a closed system, uplift by the expansion of water upon freezing, as proposed by Inglis, is possible. Figures 1–4 illustrate the sequence of events.

The film is available on loan from the Commanding Officer, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Further study of the freezing of soils and related phenomena is being carried on in that laboratory.

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6 July 1965

Retrograde Amnesia

Failure of persons to recall events that occurred just prior to a severe concussion or electroconvulsive shock (ECS) has been of considerable interest to neurologists, psychologists, and physiologists. Such failure, called retrograde amnesia, seems to imply that memory traces are initially in a relatively vulnerable state, and that they require a period to become "consolidated." In view of current efforts to identify the physical or chemical nature of the trace mechanism, great importance is attached to estimates of the length of the period of retrograde amnesia.

Currently it has become evident that the time course of consolidation, as inferred from experiments in which electroconvulsive shock is administered to animals at various times after learning, needs careful reconsideration. Shock, especially with repeated administration, has aversive effects which in many of the classical studies have led to a confounding of variables (*1*). In some cases amnestic effects have been erroneously inferred even in studies in which a single shock treatment was used (*2*). In this respect Tenen's recent report (*3*) has been of interest, for it seems to have overcome many of the objections to former studies. We would, however, like to express our concern regarding the conclusion Tenen draws. He suggests, on the basis of his own study and the studies of others, that electroconvulsive shock might exert limited amnestic effects even 3 hours after reinforcement. This conclusion seems to be unwarranted on at least two grounds:

1) Tenen employed only two intervals between learning and shock, 12 seconds and 3 hours. In order to establish the nature of the amnestic gradient, several other intervals should have been used. Since the group subjected to shock after a 3-hour interval does not show a significant amnestic effect, the only thing Tenen can conclude is that electroconvulsive shock produces retrograde amnesia when administered 12 seconds after learning.

2) The effects described in the study Tenen cites in support of the 3-hour effect (*4*) are probably not due to retrograde amnesia (*2*).

We have been carrying out a series of experiments in the psychology department at M.I.T. on the time course of retrograde amnesia. When confounding variables are eliminated, the amnestic effects of electroconvulsive shock seem to be very short, perhaps no longer than 10 seconds. This seems to apply to one-trial learning situations involving both positive and negative reinforcement (*5*).

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Chorover and Schiller object to a sentence in the last paragraph of my paper. The sentence is here italicized:

> However, the greater number of hole explorations of the delayed-ECS group over the immediate-ECS group did not reach significance ($p = .10$). *Thus it seems possible that ECS might exert some limited retrograde amnestic effects even 3 hours after reinforcement.* A longer reinforcement-ECS interval might have produced a significant difference making the findings more conclusive.

I think Chorover and Schiller have mistaken a control group for an experimental one and have elevated a *post hoc* speculation to a conclusion. The rats given shock after a 3-hour delay provided a control to assess the proactive effects on the test performance of the one-trial learning task. I originally thought that a 3-hour interval would be clearly long enough to prevent any interference with a possible consolidation process. In order to demonstrate that the delayed ECS had no proactive effects, three criteria, involving statistical comparison of groups, had to be met. Two of these were met, whereas the statistical test of the third (the one stated above) only approached significance. Although it was possible that a larger N might have resulted in the expected significant difference, several other considerations led me to speculate that a longer interval between reinforcement and ECS might be the more crucial variable. However, Chorover and Schiller are completely correct in pointing out that this study was not (nor was it intended to be) designed to explore reinforcement-ECS intervals and that one cannot *conclude* from the data presented that the delayed ECS produced any retrograde amnestic effects.

I have since conducted an experiment in which the reinforcement-ECS intervals were: immediate (about 15 seconds), 5 minutes, 10 minutes, 15 minutes, 30 minutes, 60 minutes, and 5 hours. All intervals up to the 5-hour one resulted in scores significantly lower ($p < .05$) than that of the reinforced pseudo-ECS group. The score of the 5-hour group was also lower but not significantly so. This suggests that shock delayed as much as 1 hour produces retrograde amnesia and justifies, in part, the *post hoc* speculation in the report. This interval is considerably longer than the 10-second limit suggested by Chorover and Schiller. These authors' analysis of the effects of a long interval between reinforcement and ECS found with negative-reinforcement techniques does not apply to an appetitive reinforcement. It is possible that the retrograde amnesia produced by ECS is a result of more than one mechanism and hence that the hypothesis of a consolidation process (or processes) need not always be invoked. Even if one adheres to this hypothesis, the time course of consolidation and its stability might vary with different tasks or reinforcement systems. All that is clear at this point is that additional investigation is necessary.

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