

undergo a rapid proliferative and productive process after reexposure to the antigen. The delayed reaction may, therefore, be the analogue in the skin of the proliferative burst of cellular activity in the lymph node after re-injection of antigen.

This interpretation was suggested by the work of Schlossman *et al.* (11); it supports their findings made with an entirely different system. With α -dinitrophenol conjugates of lysine peptides, they found that only conjugates capable of acting as immunogens in delayed sensitivity could elicit delayed reaction. In their case, this property was a function of size, conjugates of the octamer and nonamer being capable of eliciting a delayed reaction while smaller ones could elicit only Arthus reactions. Correspondingly, only the larger conjugates could sensitize a guinea pig to delayed sensitivity. The authors interpreted this delayed reaction as being "analogous to a local secondary response wherein immunogenic peptides can stimulate sensitized lymphocytes to produce cell-bound or free antibody."

The requirement of an immunogenic material to provide a delayed reaction in both sets of experiments makes it seem unlikely that delayed reactions can be attributed to preformed antibody of any sort. Rather the results make it appear likely that the delayed reaction is an active stimulatory process in a sensitized animal reexposed to antigenic material; this second exposure may or may not lead to conventional antibody as a secondary event. Current work on in vitro blast-cell transformations (12), and on inhibition of macrophage migration (13) in the presence of antigen, suggests that these phenomena are related to delayed sensitivity and are also proliferative or stimulatory reactions. It will be interesting to see whether immunogenic materials are necessary for these reactions also.

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Amphibian Orientation: An Unexpected Observation

Abstract. *The study of homing movements of displaced newts (Taricha rivularis) revealed unexpected features of the migratory behavior of amphibians. Newts leaving the breeding stream in the spring move not directly uphill but at an angle carrying them upstream. When they emerge after summer estivation this tendency is not evident in captures made during the autumn and winter. During the latter period, however, newly metamorphosed frogs (Rana boylei) show the same pronounced upstream migration that characterizes T. rivularis in the spring.*

The phenomenon we describe was encountered in experiments designed to determine whether displaced newts initiate their homing journey by oriented migration or random search. For this purpose "land traps" (wire-mesh fences that funnel migrating animals into escape-proof cages) were installed at moderate distances (about 13.5 to 215 m) from the banks of Pepperwood Creek, the stream in northwestern Sonoma County where most of our hom-

ing studies have been made (1-6). Several of the traps were constructed on the principle (Fig. 1) permitting one to determine whether, at the time of capture, the displaced animals were moving in an upstream or downstream direction. The design and results of these experiments have been described already (1); we now describe an odd and unexpected feature of the capture in these traps of nondisplaced members of the native amphibian population.

The traps were installed in autumn 1963, and the ensuing spring, as adults of the newt *Taricha rivularis* began to leave the stream late in the breeding season, we were surprised to find that most of the animals captured were present in the downstream halves of the cages. This showed that, at the time of interception, the newts were moving not directly uphill but at an angle carrying them upstream as well. For the remainder of that spring, and during the following years, we have been careful to record separately the numbers of captures in the upstream and downstream halves of all traps, not only of *T. rivularis*, but also of the frog *Rana boylei* and plethodontid salamanders *Aneides* and *Ensatina*.

The captures of *T. rivularis* conform to a well-defined seasonal pattern that is repeated each year (Fig. 2a). During the spring, especially in the later part of the breeding season when exodus from the water is already beginning, most captures consist of animals moving in the upstream direction. Captures cease during the ensuing dry months, when *T. rivularis* is in underground retreats, and resume with the onset of autumn rains. From then until the spring breeding season, a period during which *T. rivularis* forages on the forest floor when humidity and temperature permit, captures are distributed approximately equally in the two halves of the cages. One might perhaps expect a downstream orientation of migration during autumn and winter to compensate for the upstream movement in the spring, but, as seen in Fig. 2a, our captures reveal no evidence of this.

A possible interpretation previously mentioned (1) is that the upstream component of the terrestrial migration at the close of the breeding season is somehow an extrapolation of orientation to the current before leaving the water. While in the stream the animals characteristically face into the current, often working upstream against it; con-

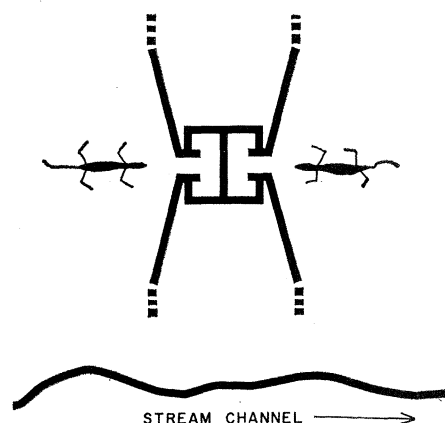


Fig. 1. Representation of traps installed near the streamside for determining whether migrating newts were moving in an upstream or downstream direction at the time of interception.

ceivably this orientation is partly preserved during their subsequent uphill migration toward summer retreats. Support for this interpretation seemed to come from captures of newly metamorphosed *R. boylii* following the autumn rains. During this portion of the year

T. rivularis, which had not been in the water since the preceding spring, showed no preferential migration in either up- or downstream directions; but the young frogs, which had just recently emerged from the water, displayed an especially marked upstream migration (Fig. 2b).

Newly transformed *T. rivularis* and *T. granulosa* captured in the traps, although recorded only for the autumn-winter period of 1963-64, also showed a preferential migration in the upstream direction. The captures of *Aneides* and *Ensatina* would appear to support the same interpretation (Fig. 2c). These salamanders, like many plethodontids, deposit their eggs on land and are terrestrial throughout their lives. Although the total number of captures was relatively small, their distribution in the traps during autumn and winter showed no marked preferential orientation in either direction, in keeping with the fact that these animals were never exposed to the stream current. Trap captures of both frogs and plethodontids were confined almost entirely to the fall and winter, and it is only captures during these seasons that are recorded in Fig. 2, b and c.

However, we have encountered evidence that casts serious doubt on the relation between direction of current and orientation of terrestrial movements. This comes from animals subjected to cranial surgery designed to identify the special senses responsible for homing orientation. When released on land near foreign segments of the home stream, these traumatized animals, unlike similarly displaced normal animals, tended to move upstream on the hillside, without regard to whether they came from up- or downstream sources. Since between collection and release they had been subjected to all of the handling and disorienting procedures incidental to collection, transportation in crowded containers, and surgery after storage in tanks at the field laboratory, it is highly doubtful that their upstream orientation at the release site is a carry-over from orientation cues gained from the current while the newts were still residing in the remote segments of the stream from which they were obtained.

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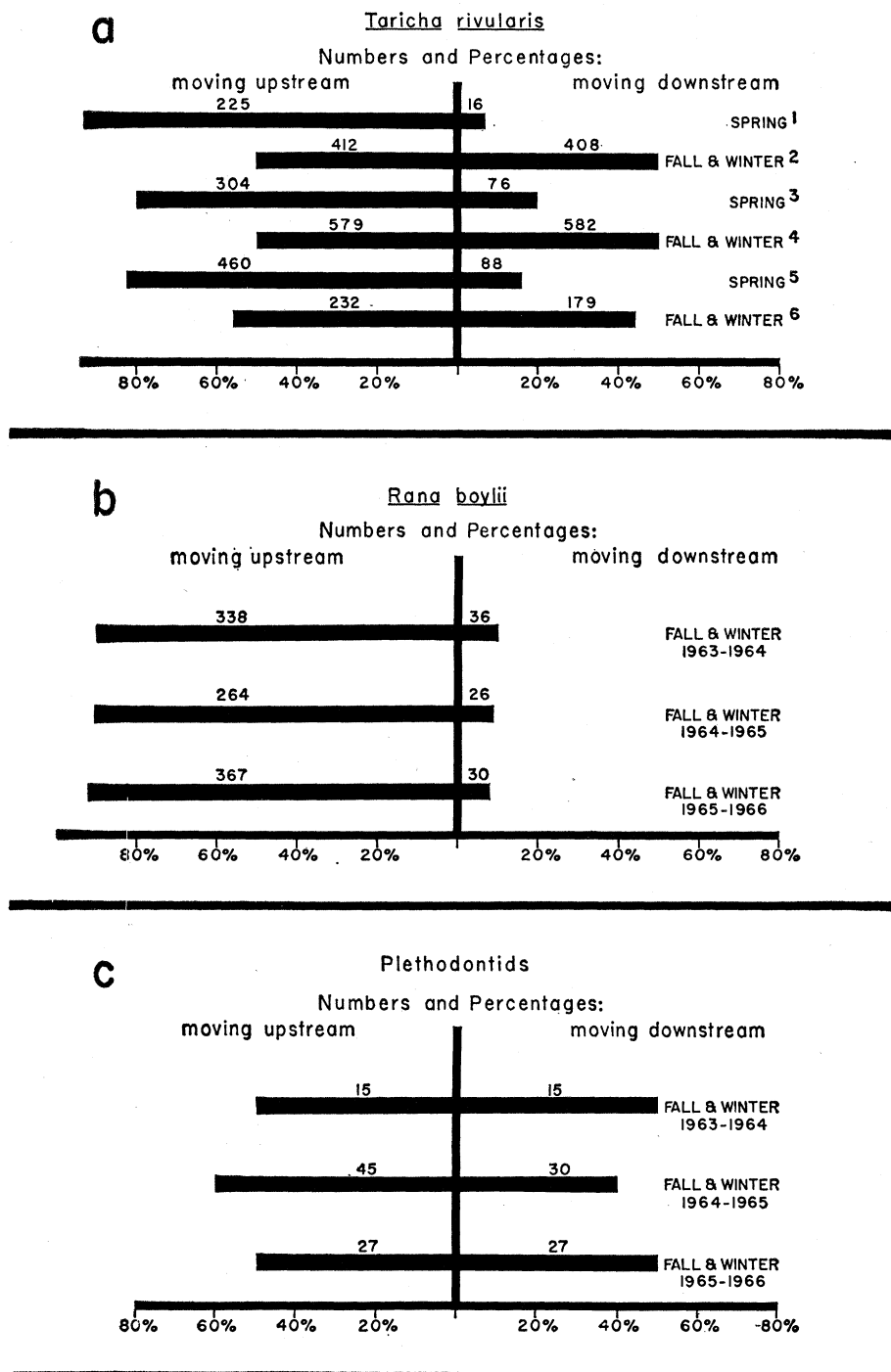


Fig. 2. Numbers and percentages of amphibians captured during movement upstream and downstream at the time of interception in land traps of the design illustrated in Fig. 1. (a) *Taricha rivularis*. Sample 1, captures made between 28 March and 24 April 1963; sample 2, between 13 October 1963 and 6 March 1964; sample 3, between 13 March and 15 April 1964; sample 4, between 29 October 1964 and 3 March 1965; sample 5, between 11 March and 25 April 1965; and sample 6, between 9 November 1965 and 13 February 1966. (b) *Rana boylii*. Captures made during autumn and winter during the same 3-year period as in (a). Frog captures declined markedly by late January or early February, and almost no captures were made subsequently. (c) Plethodontid salamanders *Aneides* and *Ensatina*. As in (b) almost no captures were made during the spring.