Differential Avoidance of Mimetic Salamanders by Free-Ranging Birds
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trypsinization for serial subcultivation (4). Membrane changes that are later reflected in changes in intracellular activity may be brought about by trypsinization. Exposure of cells to some substance (or substances) in either the medium or serum during subcultivation may also be a factor. Additionally, the possibility that this differentiation is a "cell aging" phenomenon must be considered. Further studies involving tumorigenicy, cytogenetics, and cloning will be required to more completely define the nature of this phenotypic alteration of C6 glial cells.

De Vellis and associates (15) have commonly used RG C6 cells of less than 25 passages for their studies of steroid hormone induction of GPDH, another enzyme marker for oligodendrocytes. It would be of interest to know whether GPDH is present at later cell passages.

The finding of marked GS activity as a factor of passage of cells may explain why little GS was detected previously by Nicklas and Browning (16). They reported activities that were 50- to 100-fold lower than those found in whole rat brain. In the present study, the activity of cells at 82 passages and 15 days in culture (2.137 ± 0.096) is almost as high as activities found in whole rat brain (2.940 ± 0.105). To a minor extent the present higher values may also be due to methodology. The higher amount of ATP used in our assay media results in approximately 40 percent increased activity; trypsinization of the cells causes a twofold increase in activity. Finally, this study strongly emphasizes the large amounts of GS present in C6 cells and furthermore stresses the importance of reporting passage when describing properties of C6 glial cells.

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References and Notes


9. Obtained through the courtesy of Dr. Jean de Vellis, University of California, Los Angeles.
12. L. Hertz, personal communication.

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Abstract. Members of a free-ranging avian community avoided the mimic morph of the salamander Plethodon cinereus significantly more often than a nonmimetic morph when offered with the model eft stage of Nototritalus viridescens and the palatable salamander Desmognathus ochrophaeus. This is apparently the first demonstration of the efficacy of mimic coloration of salamanders to uncaged birds.

Although the efficacy of mimicry in salamanders has been demonstrated with caged birds, there have been no attempts to demonstrate the advantage of mimic coloration to free-ranging birds (1). Attempts have been made to assess the natural mimicry coloration of moths and butterflies to wild bird communities by releasing and retrieving individuals painted to resemble palatable or unpalatable species (2). None of these studies included the use of unaltered mimics or restricted predation to birds, which are generally assumed to be responsible for the evolution of mimetic coloration.

In our study, we tested the survival value of a presumed mimic color morph of the polymorphic salamander Plethodon cinereus. Certain populations of P. cinereus have two color morphs: a red-striped morph, which is present in most portions of the species’ range, and an all-red morph, which is nearly uniformly red-orange (3). This all-red morph is thought to be a mimic of the eft stage of Nototritalus viridescens that is toxic, aposemotic, and a model for other mimic salamanders (1, 4).

In order to test the survival value of natural mimics to natural avian communities, we have developed an experimental design exposing unaltered salamanders to predation only by birds. Single salamanders were placed in 50 trays 30 cm square with an aluminum wall 10 cm tall; the top of the aluminum was bent inward, forming a 3-cm lip to prevent the escape of the salamanders (5). Each tray was nailed to a vertical section of pine log, 60 cm in length and 15 to 20 cm in diameter. Each tray contained four dead maple or oak leaves (or both) from the adjacent deciduous forest; the leaves were soaked with water just prior to each trial. The trays were placed in three rows of 18, 17, and 15 trays; the rows and trays within a row were 10 cm apart. The rows of trays were positioned between rows of trees in a 50-year-old pine plantation.

The distribution of salamanders within this grid was randomized from a hypothetical community of a million animals made up of 30 percent N. viridescens efts, 40 percent Desmognathus ochrophaeus, 24 percent striped P. cinereus, and 6 percent all-red P. cinereus; a computer generated random orders of contact for 50 individuals from this community. In each trial, an independent random distribution of salamanders was used and the actual percentages varied slightly from the hypothetical community as follows: N. viridescens, 29.4 percent; D. ochrophaeus, 41.4 percent; striped P. cinereus, 23.3 percent; and all-red P. cinereus, 5.8 percent (6). The D. ochrophaeans were offered as alternate, palatable prey because mimicry is effective only when an alternate food source is available (7).

Initially each trial lasted for 4 hours (5 to 9 a.m. and 5 to 9 p.m.); the predation rate during five 4-hour trials was 75.1 percent of all edible salamanders (D. ochrophaeae and P. cinereus). Because of this high predation rate, the length of

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Table 1. Differential survival of salamanders exposed to free-ranging birds.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Notophthalmus viridescens</th>
<th>Desmognathus ochrophaeus</th>
<th>Plethodon cinererus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Striped</td>
<td>All-red</td>
<td></td>
</tr>
<tr>
<td>4-hour</td>
<td>73 (95.9)</td>
<td>97 (30.9)</td>
<td>60 (15.0)</td>
</tr>
<tr>
<td>2-hour</td>
<td></td>
<td>60 (15.0)</td>
<td>20 (25.0)*</td>
</tr>
<tr>
<td>First seven</td>
<td>106 (99.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second seven</td>
<td>100 (99.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All 2-hour</td>
<td>206 (99.0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not significantly higher than for striped: 4-hour trials, \( x^2 = 1.039; \) first seven 2-hour trials, \( x^2 = 0.035. \)

By contrasting the survival or removal of salamanders only from trays where leaves had been moved, it is possible to test for the survival value of the preserved mimetic coloration with certainty that the mimics had been contacted by avian predators. When leaves had been moved the all-red morph of \( P. \) cinererus survived 66.7 percent of the time in contrast to the striped morph which survived 20.5 percent of the time (Fig. 1); this difference is significant (\( x^2 = 7.540, .005 < P < .01 \)). Striped \( P. \) cinererus and \( D. \) ochrophaeus survived at the same rate, and there were no differences between these and all-red morphs when leaves had not been moved (Fig. 1).

We can conclude that free-ranging bird communities avoid model and mimic salamanders while eating nonmimic salamanders and that the all-red morph of \( P. \) cinererus is a mimic of eft \( N. \) viridescens. Mimetic individuals (at a frequency of 20 percent) of a polymorphic species had a great survival advantage over nonmimetic individuals. Further utilization of our experimental design should allow a more natural demonstration of the precepts of mimicry but should be used to augment rather than replace studies with caged avian predators.

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References and Notes


3. The all-red morph of \( P. \) cinererus is found only in the northeastern United States at frequencies up to 20 percent (S. G. Tilley, personal communication).


5. The effectiveness of these trays was demonstrated 10 days after the termination of our tests. Birds had apparently left the pine woods, and all salamanders remained in the trays during these three 2-hour tests (150 animals). No leaves were moved.

6. Salamanders from the following localities were used: \( N. \) viridescens efts, near Rensselaerville, Albany County, New York; \( D. \) ochrophaeus adults, Albany and Ulster counties, New York; striped and all-red \( P. \) cinererus adults, Franklin County, Massachusetts. The test grid was located on the E. N. Hayck Preserve, Rensselaerville; \( N. \) viridescens, \( D. \) ochrophaeus, and striped \( P. \) cinererus are native. Desmognathus ochrophaeus with red coloration were not used.


8. All-red \( P. \) cinererus survived more often than striped \( P. \) cinererus during the last five trials (\( x^2 = 4.828, .025 < P < .05 \)); the last six trials (\( x^2 = 9.204, .001 < P < .005 \)), and the last seven trials (\( x^2 = 5.096, .01 < P < .025 \)).

9. The following percentages of trays leaves had been moved: \( N. \) viridescens, 22.8; \( D. \) ochrophaeus, 18.6; striped \( P. \) cinererus, 23.9; all-red \( P. \) cinererus, 22.0. No pairs of values are significantly different by chi-square analysis.

10. We thank the E. N. Hayck Preserve and its director R. C. Dalgleish for support. S. G. Tilley pointed out this case of mimicry and helped us obtain specimens. R. G. Jaeger, D. R. Formanowicz, Jr., and P. K. Ducey helped formulate the experimental design, and the last two with C. C. Bodenweiser, M. L. Manis, and M. S. Bobka helped with collection of animals and data.

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