The Evolutionary Strategy of Mimicry

Patricia A. Lane

EVOLUTIONARY ECOLOGY IS AN EXCITING area in biology that centers on the multitude of ways species adapt and evolve in their ecosystems. Unfortunately, evolutionary processes even on an ecological time scale are not very suitable for laboratory study, especially for beginning students. It is difficult to impress upon students the many ways species solve the difficult problems of survival when all of their learning must come second-hand from textbook descriptions. Thus, the richness of so many important biological phenomena (and associated examples from natural history) go unappreciated in the standard curriculum. In particular, adaptation, natural selection, and coevolution are concepts difficult to understand.

The following laboratory exercise can be used for both high school and college courses. It gives the students an opportunity to participate in ecological processes that are mediated by natural selection. We have found that students enjoy the laboratory and come away with an enhanced awareness of the workings of the natural world. We have used this exercise in an introductory course entitled "The Diversity of Organisms" to illustrate one of the many ways organic diversity arises. The group Insecta, which represents the most prolific animal group in terms of number of species, provides an endless array of ingenious examples and thus, this exercise is included as part of the study of insect diversity in our curriculum. This exercise centers on the concept of mimicry and can be used to illustrate the importance of adaptation, natural selection and coevolution.

It is best to introduce the concept of mimicry by discussing or displaying examples of protective coloration (crypsis) with which the students are more familiar: the arctic hare, the walking stick, the flounder, the polar bear, birds' eggs and feathers, the buff color of most desert animals, the African chameleon, and lizards. It should be stressed to the student that protective coloration is widespread throughout the animal kingdom as are adaptations to the selection pressure of predation. The students then follow the laboratory handout.

Preparation

The supplies and associated preparation are minimal. A few days before the laboratory, the instructor prepares the raisins as follows: one-half are soaked overnight in a solution of 1 box powdered alum dissolved in one liter of reconstituted lemon juice. The other raisins are soaked in water. One kg of raisins is needed per 100 students. After 24 hours, the raisins are dried on paper towels and then mixed together thoroughly. The bad and good tasting raisins are indistinguishable. Twenty raisins are placed in a baggie for each student.

Resource Materials

Emlen (1973) discusses crypsis (protective coloration) and aposomatic coloring (warning coloration). The paperback volume by Wickler (1969) provides an excellent survey of mimicry in both plants and animals with many interesting examples that could be discussed in a lecture period or represented in laboratory displays.

In addition, a variety of resource materials on crypsis and mimicry is available from standard biological supply houses. Colored pictures or film loops of cryptic and mimetic organisms, displays or pictures of the coloration patterns of butterflies, lizards, snake skins, or mollusc shells can enhance the laboratory. Films on several types of mimetic relationships can be obtained from Pennsylvania State University, 103 Carnegie Building, University Park, Pennsylvania 16802.

Laboratory Handout

Insects have undergone an amazing adaptive radiation. In the evolution of the various species, several groups

The author is assistant professor of biology at Dalhousie University, Halifax, Nova Scotia, Canada and adjunct assistant professor of biology at the W.K. Kellogg Biological Station, Michigan State University. She received her Ph.D. degree from the State University of New York at Albany in 1971, and has been the recipient of fellowships from the Ford Foundation and the American Society of Limnology and Oceanography and the Ecological Society of America. Lane's research interests center on the structure and stability of aquatic communities, especially in regard to man-induced perturbation and she is currently researching this area on the Bedford Basin and Gull Lake. She has participated in several symposia on aquatic community structure, and has presented papers on niche analysis at professional association meetings. She is an elected member of the American Naturalists Society and holds memberships in a number of other professional societies including the American Association for the Advancement of Science, the Ecological Society of America, and the International Association of Theoretical and Applied Limnology.

have demonstrated rather ingenuous strategies for persisting on the earth. We are going to study how some insects have solved an old and troublesome problem, namely, how not to be eaten by a predator. At the very best, being eaten is a rather inglorious and unpleasant end to the whole business of living.

Because some insects fly in the air and often feed conspicuously on trees and bushes, they are easy prey for hungry birds and other predators. To avoid these predators, insects possess an extensive and impressive array of adaptations, many of which involve visual images. For example, some insects are colored like their surroundings so that the predators have a difficult time finding their prey. This phenomenon is termed protective coloration. Other insects, especially butterflies, have startle mechanisms which include eye spots on their wings. When a predator looks at the butterfly, the eye spot resembles a vertebrate eye and thus, the predator is afraid to attack since the predator believes the larger predator is eyeing him. Other insects which are poisonous, dangerous or otherwise noxious, advertise the fact. That is, they display warning coloration. They have brightly colored bodies and wing patterns which warn predators to stay away (fig. 1).

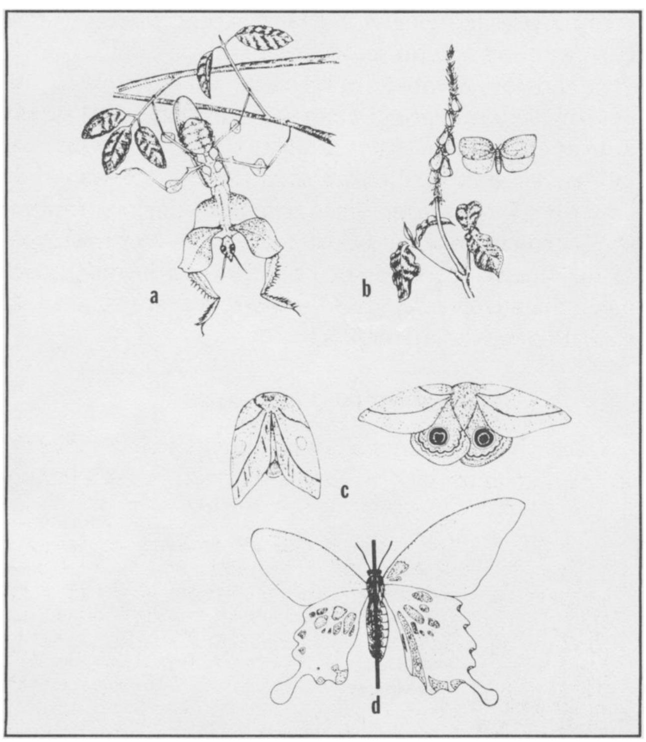

FIGURE 1. Some examples of protective and warning coloration and mimicry.

(a) A mantid pretends to be an African devil flower.

(b) A butterfly pretends to be a flower inflorescence.

(c) The peacock butterfly has dangerous looking eyes on its wings.

(d) The right side of a mimetic butterfly is compared to the left side of the model butterfly. Both are members of the swallow-tail family.

An interesting alternative to being noxious, is to pretend to be noxious. This strategy is called mimicry, whereby an edible prey or mimic has the same coloration and markings as an unpleasant prey or model. It is rather like sweet little children dressing up as witches and goblins for Halloween. In this grim evolutionary game, however, the reward is not a candy apply, but rather an enhanced ability to be avoided by predators and a few more hours or days of existence. Since a predator cannot distinguish the bad-tasting models from the costumed mimics, the predator eats neither models nor mimics. Several different sets of models and mimics exist among the insects.

Jane Brower (1960) has studied mimicry under controlled laboratory conditions. Using starlings, frogs or other predators, she observed and measured the biological mechanisms involved in mimetic relationships for a variety of prey organisms. For example, she stained mealworms with various colored dyes and simultaneously made some of the prey inedible by dipping them in quinine. The unsuspecting starling quickly learns which are colored or mimetic mealworms (fig. 2).

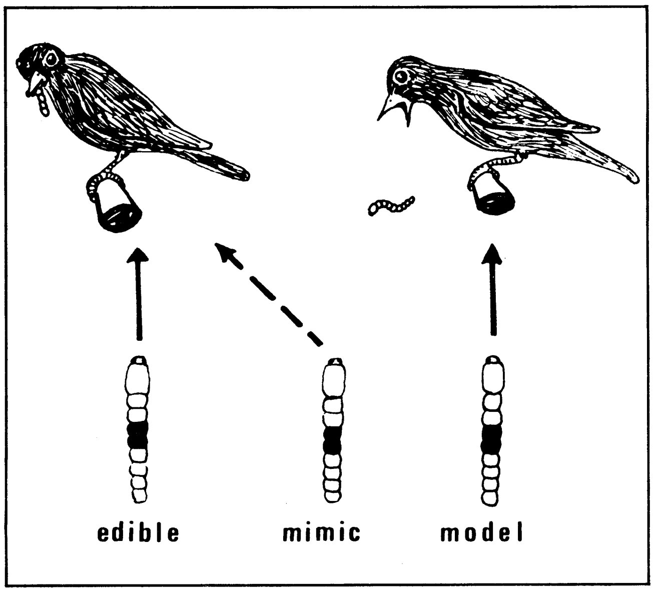

FIGURE 2. Diagram of typical mimicry experiment with starlings and insects (Brower, 1960).

(a) Edible mealworm *(Tenebrio)* larvae were banded with orange paint and dipped into distilled water. This tests the effect of taste.

(b) Model larvae were banded with green paint and dipped in quinine solutions.

(c) Mimetic larvae were banded with green paint and dipped in distilled water. The starling soon learns not to eat mealworms.

Since it was not very practical to cage and train innumerable starlings not to eat green painted, quinine-soaked meal worms in this laboratory, we decided you would get the feeling of mimicry more effectively if you became the predator. A variety of prey were suggested as possible palate-ticklers for you. Would you consider chocolate-covered ants or honey-dipped grasshoppers? After much deliberation, we decided on a rather rare, yet delicious species of insect: the raisin bug.

Go to the demonstration table and obtain a package of raisin bugs, neatly packaged in a baggie.

You are looking hungry already, but please wait for instructions on how to be a proper predator before devouring your prey. Note that we have cleaned the raisin bugs for you by stripping off the hard carapaces, gauze wings, and bristly legs; thus, these specimens will probably not look like the raisin bugs you are accustomed to seeing. As you may guess, raisin bugs come by their name quite understandably, since they look much like raisins. That any of you would mistake them for raisins, however, is quite ridiculous, since any student of biology should be able to distinguish a raisin from an insect. (See note.)

We are going to explore the strategy of mimicry as follows: in the bag, there are good and bad tasting raisin bugs. The good tasting insects are mimics and the bad tasting insects are models. The mimics and models are both called raisin bugs which is their common name. Actually, the little brown pile in front of you is composed of two different species which are indistinguishable to you, the predator.

Procedure

1. Choose a prey randomly and eat it. Score +1 if it is a palatable raisin bug and -2 if it is an unpalatable raisin bug. Record what each prey is (model or mimic) and their scores in order of your consumption in Table 1. We are giving more points to the inedible models because theoretically the predators, after consuming an inedible prey, would wait twice as long to attack another raisin bug.

2. Every time you eat two or more raisin bugs of the same type in consecutive order, add 1 extra point for a mimic and subtract 1 extra point for a model. Thus, whether you receive a mimic or a model, your reaction to that prey will be reinforced.

3. When all of your prey are devoured, calculate your total score. If it is positive then you will survive another day; if it is negative, then you will die of starvation by midnight. Calculate also the ratio of mimics to models. Everyone in the class will put their results on the board so that conclusions can be made on how the model: mimic ratio effects the survival of you, the predator.

4. Answer these questions: (partial answers are given in parentheses below).

(a) What is the significance of the model to mimic ratio to the predator's survival? (As this ratio increases, the predator's survival is enhanced.)

(b) Why is mimicry important in a consideration of coevolution and local adaptations? (First, the degree of perfection the mimic attains in resembling a model gives a good indication of the fine tuning natural selection achieves in sets of coevolving species. Second, geographic studies, centering on several sets of models and mimics, with and without high predation pressure have demonstrated that a high and sustained selection pressure is necessary if the mimetic patterns are to be maintained in the populations and that slight differences in local conditions can greatly alter the effectiveness of the mimicry. Third, these studies have also shown the great speed with which mimetic adaptations can be established and maintained in populations and that evolutionary events can often proceed on an ecological time scale.)

(c) How significant is predation as a selection pressure? (Apparently predation is an extremely effective selection pressure. The studies of mimetic organisms and those exhibiting cryptic or protective coloration have well documented the role of predation as a major selection pressure.)

This exercise is particularly effective because of the students' unusual involvement as they pretend to be bird predators and because the calculations and questions at the end of the laboratory necessitate that they understand the basic phenomena under consideration. This laboratory also reduces the monotony of endless dissections and test-tube type experiments.

TABLE 1 Data table for raisin bug mimicry experiment

PREY NUMBER	MODEL	MIMIC	SCORE
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			
		TOTAL SCORE	

Acknowledgment—Susan Silcox developed the alum-lemon mixture and Goldie Gibson drew the figures adapted from Wickler (1969). Mary Primrose photographed the figures and Anna Taylor typed the manuscript.

Note—Each year out of a class of 500 students we have 2-3 who believe the raisins are insects. Reluctant student predators should be carefully taken to the side and convinced they are not being asked to eat uncooked insects. These students should be spared as much embarrassment as possible.

(Concluded on p. 223)

at what age level there was the greatest interest in reading natural science materials. For this purpose we selected a cross-section of 5,000 pupils from grades 4 through 12 from a large area covered by the program. My task was to tabulate the questions asked most frequently by pupils. At the same time I kept a listing of the grade level from which the question came and recorded the difficulty of the question. The editors of *Pacific Search* published the most challenging questions monthly. Needless to say I spent many hours doing research to find the correct answers to the questions selected. I learned a great deal from the kids in the process. The final tabulation on both surveys revealed almost identical results. Below are listed the eight specific animal groups selected for the eight issues:

(1) November 1973—On Spiders
(2) December 1973—On Nonpoisonous Snakes
(3) February 1974—On Poisonous Snakes
(4) March 1974—On Bats
(5) April 1974—On Carnivores
(6) May 1974—Spiny-Skinned Mammals
(7) June 1974—Odd Facts On Birds
(8) July 1974—More Odd Facts On Birds

I have received reprint rights from *Pacific Search* to photocopy the individual tear sheets of these Questions and Answers and would be happy to send one *page* to any teacher reader. (Please include a stamped envelope.) However, if you live in the Pacific Northwest you can obtain a back issue copy at most public libraries.

Now to the results of both parts of the survey. The 4th grade level showed the greatest number of logical, animal biology questions as well as the highest interest percentage in the reference reading on animals. Why? After a series of seminars with elementary school librarians, the answer became clear. It seems that reading understanding begins to "gel" late at the end of the 3rd grade and that reading comprehension as well as the enthusiasm for this new magical media reaches its highest plateau in the 4th grade. In brief, I was told that the 4th grade pupil literally reads everything in sight in natural sciences with an eagerness never again exhibited during his or her school experience. Five librarians checked the titles of books that were signed out for home reading throughout the year and affirmed the evidence of the survey. But in many cases enthusiasm took a definite drop by end of the 6th grade.

The final highlight of the Title III Teacher-In-Residence program was and always will remain an unsolved mystery to me. The mystery centers around a TV program. I was asked to be a panel member on a television show along with two members of the local Humane Society. The program was to be an hour long with the first half hour devoted to a lecture-demonstration with living animals and brief remarks by the Humane Society members. The topic was "Why You Should *Not* Have An Exotic Animal As A Pet." The objective was to educate the general viewing public against the practice of buying that "cute little monkey" or "that adorable cougar cub" as a household pet. For my part of the program I brought from the Woodland Park Zoo a baby cougar cub, a kinkajou, a Great Horned Owl, and a ten foot Burmese python. All these exotic animals were from my own personal collection and I had spent years bringing them to the point where handling was a comparatively safe venture. While I was handling these fascinating animals before the TV camera and my unseen audience, I carefully explained the potential dangers involved in what I was doing . . . (perhaps I should have stripped to the waist to show my scars!). In any case, I finished my lecture-demonstration without incident. The second half of the hour was for telephone calls to the station from the audience. We were supposed to answer questions related to the topic under discussion. In addition to my remarks against the average person having a wild animal as a pet, there were vivid examples by the two members of the Humane Society using wild animal pets such as skunks and raccoons as well as monkeys; the futility of the program was only too evident. Questions asked us not only by teenagers but by adults included these: "Where can I buy a baby cougar and does it need shots?" "Can you send me a list of the proper diet needed for a big python like the one you have as a pet?" I don't think I was ever so close to throwing in the towel on the entire program as I was at the end of this TV session. I probably should not have been surprised at the text of the replies. I had encountered the same attitude and response among school children every day in my classroom presentations. Proof of this is in a photograph featured in the *Seattle Times* showing a 3rd grade pupil, a cute lovable child fondly embracing a ten foot boa constrictor. There is no trace of fear on the face of the child. There is an excuse for this little girl; she probably never read about pythons or even touched one before. But what about the older populace?

If you have the opportunity to borrow the preserved jaws of a large snake, present it to your biology class as a teaching tool. Have the pupils examine the rows of needlelike curved teeth (about 100) and speculate on the extent of the bite they might count on receiving. I have several of these head skeletal structures which I use in class prior to allowing a student to wrap the big snake around his or her neck. The warning works.

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