MIMICRY

ESA *lab*

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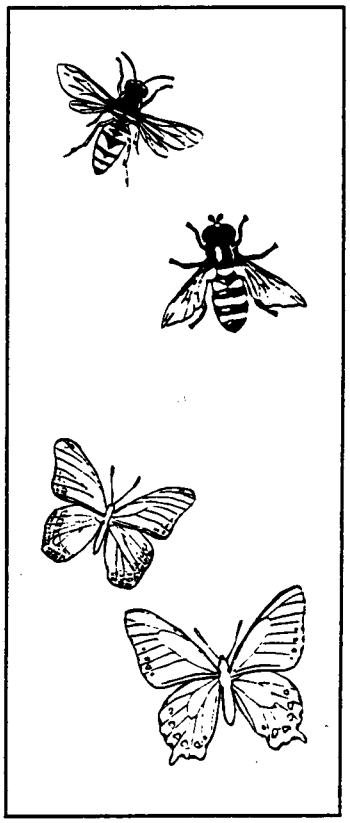
INTRODUCTION

One way or another, most animals must avoid being eaten by predators. Some animals are bad-tasting or dangerous, for example, and predators learn to recognize them by their bright color patterns and leave them alone. The black-and-yellow bands of yellow jackets clearly indicate to potential predators that these wasps can sting and are to be left alone. Animals which are good-tasting or cannot defend themselves directly must resort to other ways to avoid being eaten. One way is to look like an animal that is bad-tasting or dangerous; the predator then learns to avoid all those animals that look like the noxious ones. There are flies and beetles, for example, that have distinct yellow and black bands and look like yellow jackets, and predators avoid them even though flies and beetles cannot sting like yellow jackets.



Mimicry is the superficial resemblance of one organism by another. Batesian mimicry is the form of mimicry in which palatable prey resemble bad-tasting or noxious non-prey enough so that their predators cannot distinguish between them. After a number of distasteful encounters, a predator learns to avoid prey with this appearance. There are three elements in Batesian mimicry: the **model** is the noxious non-prey species, the **mimic** is the palatable prey species that resembles the model, and the **predator** is the signal receiver that can't distinguish the mimic from the model.

Many examples of mimicry are found in butterflies. Pipevine swallowtails are bad-tasting because of plant poisons taken into their bodies during larval feeding on pipevine leaves. Several butterfly species that do not take in plant poisons as caterpillars, including red-spotted purples, look very much like the pipevine swallowtails because both species are dark with bluish iridescence and a row of light spots on the hind wings. In this case, the pipevine swallowtails are the models, the red-spotted

purples are the mimics, and blue jays and other birds are the predators that learn that bluish iridescence on the hindwings is a signal that the butterflies are bad-tasting. Thus, the predators leave both species alone.

The factors that determine the effectiveness of mimicry are 1) the frequency (relative numbers) of the mimic, 2) the degree of distastefulness of the model, and 3) the degree of perfection of the mimic (Pilecki and O'Donald, 1971). When the mimic is frequent, a predator encounters many palatable individuals displaying the signal, so the predator is less apt to recognize the signal as something noxious. When the model is highly distasteful, a predator learns the meaning of the signal more rapidly, with stronger behavioral deterrence, than when the model is less distasteful. When the mimic does not resemble the model perfectly, a predator may recognize the difference and so feed preferentially on the palatable species.

In this experiment you will examine the responses of native birds to different frequencies of a mimic species while holding the other two parameters constant - the degree of distastefulness and the resemblance of the mimic to the model. The experimental procedure follows that used by O'Donald and Pilecki (1970). Local birds will be the predators, and they will feed from a feeding tray placed outdoors. Prey of three colors will be presented to the birds: all prey of one color will be completely palatable, 3/4 of the prey of the second color will be palatable (few models, many mimics), and 1/4 of the prey of the third color will be palatable (many models, few mimics).

LABORATORY OBJECTIVES

conceptual

1. Learn about the components of Batesian mimicry.
2. Measure the effectiveness of mimicry when the relative numbers of models and mimics are changed.
3. Observe the feeding behavior of birds and determine whether it can be modified through learning.
4. Conduct a manipulative experiment and make inferences from observed results.

procedural

5. Learn to graph experimental data.
6. Use a Chi Square test to analyze experimental results.
7. Complete a written report describing and discussing the results of an experiment.

MATERIALS

lab equipment

large finger bowls (5)
several (1-5) cookie presses
top-loading balance (to 0.01 g)
balance for heavier weights
weighing trays and spoons
max-min thermometer
small rulers (15 cm / 6 in)
refrigerator
feeding tray

disposable items

white flour (2 kg/5 lb)
lard (solid shortening) (1 kg/2 lb)
food coloring (red, blue, green, yellow)
quinine sulfate (5 g)
disposable gloves
wax paper
masking tape
pens
plastic knives (or single-edge razor blades)
plastic petri dishes
feeding array charts

PROCEDURE

PRELIMINARY PREPARATIONS

Before beginning this experiment, a feeding tray must be prepared and set up outdoors in an area frequented by local birds. To accustom the birds to feeding from the experimental site, the feeding tray should be stocked with sunflower seeds for a week or two prior to beginning the experiment.

CHOOSING PREY COLORS

1. As a class, you will discuss and choose the colors for the prey. Think about what different colors signify in nature. Red, orange, and yellow often are **warning colors** that alert predators to the noxiousness of potential prey (e.g., orange-colored monarch butterflies). Most predators see these organisms clearly and learn to avoid them. Green is usually a **cryptic color** for an animal since it blends in with the background vegetation (e.g., caterpillars on foliage). However, these colors may have different meanings in different circumstances (e.g., the red color of fall fruits). Of course, some colors are more common in nature than others. If the birds at the feeding tray have any existing bias for or against a certain color, that bias could be countered by assigning colors opposite to their usual meaning (e.g., a warning color assigned to all-palatable prey). To avoid bias as much as possible, one could try all possible combinations of color and percent palatability. The colors that can be used in this experiment are yellow, blue, green, red, orange (red+yellow), and purple (red+blue).

2. Record the color schemes proposed by members of the class, and vote for your preferred color scheme. The scheme that wins a majority will

colors of yellow, green, and blue will be used, but in each case you should substitute the colors chosen by the class.

color chart

prey type	default	class color scheme
fully palatable	yellow	_____
3/4 palatable	green	_____
1/4 palatable	blue	_____

PREPARING THE PREY

1. The prey for the experiment are artificial insect larvae (like caterpillars or mealworms) made from a delicious recipe of flour and lard. A group of students will be assigned to prepare the prey. Those not preparing the dough should go on to preparing the arrays (below). Begin with 1 kg (2 lbs) of lard in a large bowl and add 1.6 times as much flour by weight. The warmth of your hands will make the dough seem gooey while you work with it, but it will harden somewhat when refrigerated. Wear disposable gloves when working with the dough to avoid staining your hands or adding unwanted flavor to the dough.

adding color

2. Once a large mass of dough of the 1.6 to 1 ratio has been mixed, divide it into three approximately equal lumps and place them in separate bowls. Add food coloring to each of the three masses of dough and mix thoroughly to produce the colors chosen by the class (e.g., [yellow], [green], [blue]. You will have to judge when a good color has been reached; try for bright, distinctively different colors.

adding flavor

3. We will use quinine sulfate (or bisulfate), a compound known to be distasteful to a wide variety of animals, to make the bad-tasting "model" species. Separate out 1/4 of the [green] dough and 3/4 of the [blue] dough to make distasteful. Weigh the dough and add quinine sulfate in equal proportions to each dough mass that is to be distasteful. Use 0.75% quinine by weight; the total amount is not very important in this experiment, as long as the same proportions are used. Mix the quinine sulfate into the dough thoroughly. Record all pertinent details (e.g., how much quinine sulfate and dough of each color were used). **LABEL** each lump of dough. Although quinine sulfate is bitter tasting, it is not poisonous; in fact, it is used by humans in the treatment of malaria.

making the prey

4. There should now be five lumps of dough: palatable [yellow], palatable [green], distasteful [green], palatable [blue], and distasteful

[blue]. Once each lump of dough is thoroughly mixed, use a cookie press to produce long, cylindrical, spaghetti-like strands 3 mm in diameter, stretched out on wax paper. If the dough is too soft to make the strands, place it in a freezer for 5 or 10 minutes and then try again.

5. Using plastic knives and small rulers, cut the strands on the wax paper into segments 15 mm in length. Mark the dough and prey carefully so as not to mix up models and mimics. Clean the cookie presses thoroughly with soap and water after each use (i.e., take them apart to do so).

cutting and marking prey

PREPARING THE ARRAYS

1. While some work with the dough, others will be assigned to prepare randomized arrays (charts for the placement of the artificial prey on the feeding table; a sample is shown in Figure 1) for presenting the artificial prey to the birds. The prey will be placed on a feeding table marked into 100 equal rectangles, with one prey item placed within each rectangle. During the experiment the relative frequencies of the three colors remain about the same - 1/3 [yellow], 1/3 [green], and 1/3 [blue] - while the ratios of mimic to model differ among the colors. On average, all [yellow] prey, three of four [green] prey, and one of every four [blue] prey will be palatable. Assign random numbers using the blank chart and the random number table (Table 2) on the on the following pages and Table 1 below.

TABLE 1: codes to match prey colors with random numbers.

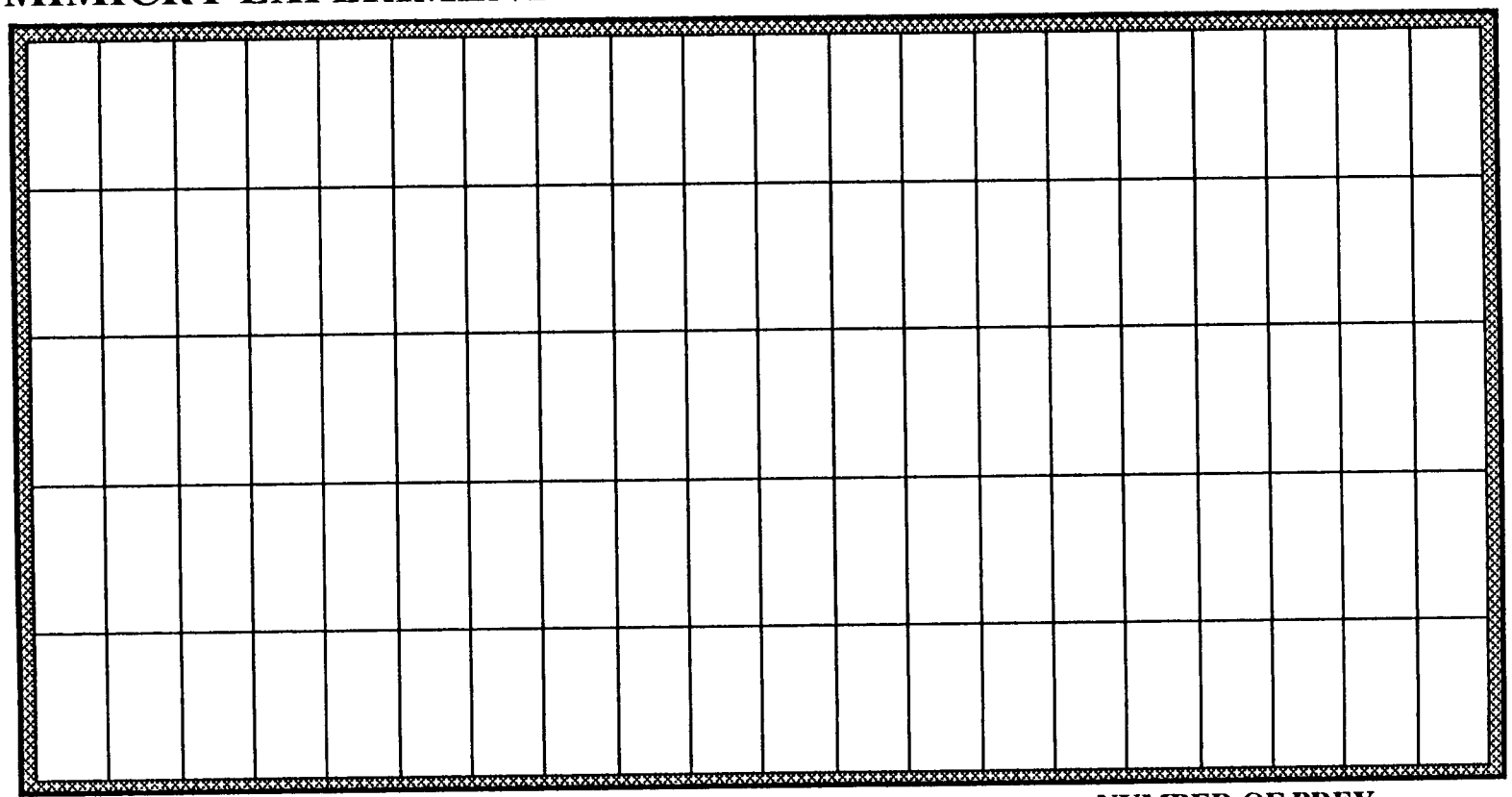
prey type	default color	actual color	%	random #s
palatable-all	Y [yellow]	_____	32	00-31
palatable (mimic)	G [green]	_____	24	32-55
distasteful (model)	(G) [green]	_____	8	56-63
palatable (mimic)	B [blue]	_____	8	64-71
distasteful (model)	(B) [blue]	_____	24	72-95
		disregard		96-99

2. To prepare the randomized array, first make a pencil mark somewhere on the random number table (Table 2). Then, start reading the random digits two at a time for each rectangle on the feeding tray and assign a prey of one of the five species to each rectangle according to its pair of digits. You needn't record the number for each rectangle; just record the type of prey. For example, a rectangle with digits 4 and 8 would receive a palatable [green], and one with digits 8 and 0 would

randomizing the array

MIMICRY EXPERIMENT

ARRAY # _____



NUMBER OF PREY

	Set out		Remaining		Removed
[Y]	_____	-	_____	=	_____
[G]	_____				
[Ⓖ]	_____	_____ -	_____	=	_____
[B]	_____				
[Ⓑ]	_____	_____ -	_____	=	_____

	DAY AND DATE	TIME	WEATHER
ARRAY SET OUT:	_____	_____	_____
ARRAY REMOVED:	_____	_____	_____

TABLE 2: A table of random numbers

37038	58013	61758	07003	81490	56318	61697	00127	45420
09009	64216	88989	74327	28326	72162	78096	32482	88078
01428	58217	72559	92996	75948	37289	39515	74318	62220
23115	90913	48032	75698	69192	79393	62544	21855	59137
01383	71509	61221	10895	54896	50910	96284	39564	29591
73917	55199	19133	80487	63773	24879	67647	49064	71339
74950	96643	49456	49606	73857	13998	40522	48994	25856
88262	55569	17607	73563	46125	72913	13306	13622	80666
49358	20406	38537	19009	52487	39016	69007	39853	29665
16083	02275	22574	12248	45220	72962	87495	76190	29364
44584	34997	81223	63672	37480	33315	00014	34695	23620
23482	34429	94737	36060	19232	38382	67123	02049	27091
27689	05794	83721	47817	30144	09185	33137	45142	65108
98653	07982	21184	22216	89786	37832	47849	23955	33272
47854	98433	95244	16132	82975	00247	28980	26290	15386
44163	80518	85946	26722	43008	80008	29159	65288	58299
28531	56275	67590	00892	41398	07049	55692	46566	74120
11411	55832	70565	60827	28608	39309	96048	48994	55139
83036	49646	66208	40144	71917	35989	59947	87578	85924
67164	27438	98716	02706	55251	71570	46778	12278	19667
26850	07068	51320	68564	07612	11021	75983	51898	89866
75250	59178	29782	82859	19585	13371	98192	38055	09608
96544	88427	03087	56285	55915	82689	69786	20369	96039
28049	14324	52744	73197	42127	68608	41188	95259	37421
34453	50642	06521	39013	46751	23048	11001	03121	18602
27159	92713	10802	77527	13933	04650	01535	68227	21900
16776	17307	33308	52464	17532	49696	90265	00105	43042
21517	20714	97505	67830	40635	98325	33405	59014	26416
75689	01582	70654	99507	21375	88765	85255	89817	34891
86665	74756	48811	75834	78482	87596	85822	15676	69020
03610	79791	69346	57375	23081	46295	23617	72285	86171
59992	25114	33730	43552	70908	38050	17933	44217	58262
93385	00411	56195	23328	12068	98360	70961	85298	35819
47093	59203	34674	88085	95169	41026	51043	31827	21240
46438	81486	32643	43505	76782	10865	01712	18684	67722
95881	56988	38845	24120	46556	54141	60265	66481	39518
35607	92482	22574	85085	91669	29166	52598	76742	07039
57488	76631	74527	40578	33044	29797	33622	45511	19443
74833	19419	49554	75369	73547	20012	27521	45499	55537
67188	49300	79174	34887	04079	43525	18129	26539	73509

receive a distasteful [blue]. Digits 9 and 8 would be ignored, with the next pair of digits assigned to the same rectangle (i.e., don't leave any rectangles blank). The simplest code to use on the charts is to let Y, G, and B (or R for red, etc.) stand for the appropriate color, with a circle around the letter for each prey item that is distasteful (that is, a model; see Table 1). A total of 14 charts will be needed to run the experiment for a week, one to be used to fill the feeding tray each morning and one each afternoon. Prepare the charts in teams of two students, with one reading the pairs of random numbers while the other fills in the rectangles of the chart with the correct prey codes. Figure 1 shows a sample chart.

FIGURE 1.
sample array

MIMICRY EXPERIMENT **ARRAY #** sample

Y	(B)	B	G	G	G	(B)	Y	G	Y	G	(G)	(B)	(G)	G	G	(G)	G	B	(B)
(B)	Y	Y	G	(B)	Y	(G)	Y	(B)	(B)	(G)	Y	(B)	Y	Y	(B)	(B)	G	(B)	(B)
Y	G	(B)	(B)	B	(B)	B	Y	G	Y	Y	G	Y	G	G	(B)	(B)	Y	(B)	(B)
Y	(B)	Y	B	Y	(B)	(G)	Y	B	G	G	(G)	Y	(B)	Y	Y	Y	(B)	G	G
Y	G	G	G	Y	B	(B)	(B)	(B)	Y	Y	(B)	G	Y	(B)	(B)	B	(B)	G	(G)

NUMBER OF PREY

		Set out		Remaining	Removed
DAY AND DATE TIME WEATHER	[Y]	29		____	____
ARRAY SET OUT: ____ ____ ____	[G]	24	32	____	____
ARRAY REMOVED: ____ ____ ____	[G]	8			
	[B]	8	39	____	____
	[B	31			

PREDICTIONS

1. Which color of prey do you think the birds will take the fewest of after one week of feeding on the artificial prey? _____
2. Which color prey will they take the most of? _____
3. Palatable prey of which color will be the most **protected** from bird predators? _____

FINAL PREPARATIONS

Once the prey and charts have been prepared, assemble the materials for the experiment. For each array, prepare five small petri dishes labelled Y, G, Ⓖ, B, and Ⓑ (or similarly labelled for whatever colors you chose). Place only one type of prey in each dish. You may pick up the prey with your fingers. Make certain that there are enough artificial prey in each dish, including two extras. Store these materials in a refrigerator until they are needed.

timing

1. Place the artificial prey on the feeding table twice each day: set out the first array between 8:00 a.m. and 9:00 a.m. and remove it at noon. Set out the second one at noon and remove it between 3:00 and 4:00 p.m. Run the experiment for one week. You will see that birds rarely sample the prey on the feeding table; they generally land on an edge of the table, hop over to pick up a prey, and then fly off to a nearby tree to eat it.

scheduling

2. Sign up for times during the week to help run the experiment. There are three times in each day that someone is needed: **morning** - to set up the first array; **noon** - to count, record, and remove the prey that remain on the feeding table and to set up the next array; and **afternoon** - to count, record, and remove the prey that remain. At noon and in the afternoon, you do not need to record the location of remaining prey; we are examining the rate of feeding of the birds specifically on the three colors of prey, so simply count the number of each color left, and then remove them all. Record and **remember** the times you are responsible for working on the feeding tray.

observations

3. Observe the birds at the feeding table for at least 20 minutes during the first day of the experiment and for 20 minutes during the last three days.

4. During scheduled lab time, we will visit the feeding tray so you know its location. The experiment will begin in the morning after preparing it in lab, so the first person to sign up will have to ensure that all remaining sunflower seeds have been removed before putting out the first array.

weather records

5. You will also set up a max-min thermometer next to the feeding table. This instrument records the highest and lowest temperatures attained since the last observation. Your instructor will demonstrate its use. You may wish to supplement these measurements with notes about the weather directly on the charts.

6. After one week of running the experiment, enter the daily feeding

totals in the data chart provided below. Graph the percent of prey of each color removed day by day. What trends do you see? You may total morning and afternoon feeding into a summed feeding total for each day, or you may graph them separately. The results provide some indication of the effectiveness of mimicry and the impact of differences in the mimic-to-model ratio. Because the three colors of prey are presented in equal abundances, the preferences exhibited by the birds should be related to the percent distastefulness of each.

DATA RECORDING AND ANALYSIS

DATA CHART

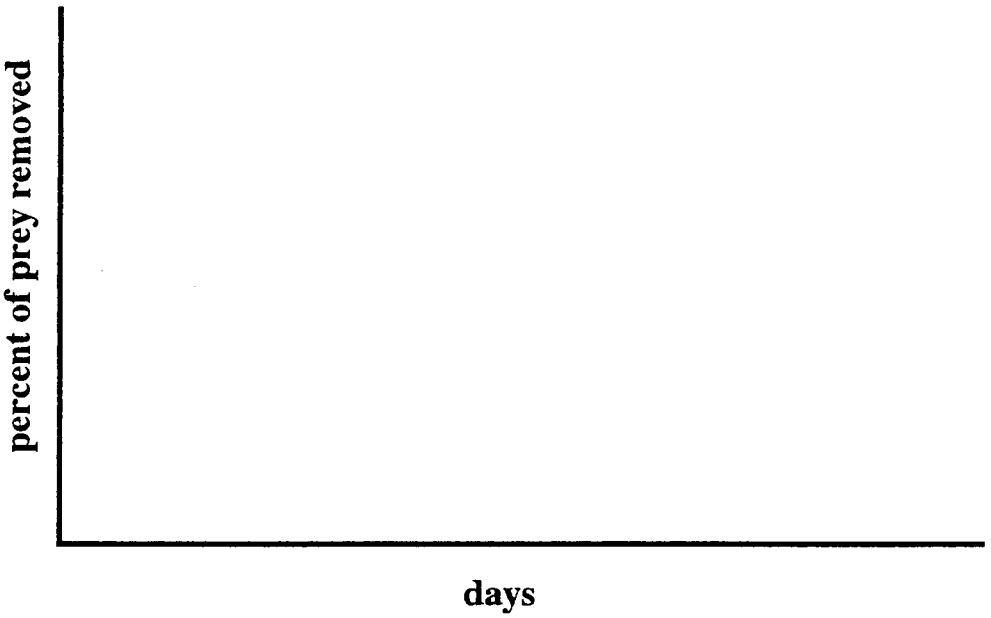
Day	percent of prey removed (write colors in blanks)			weather conditions
	_____	_____	_____	
day 1 a.m.	_____	_____	_____	_____
day 1 p.m.	_____	_____	_____	_____
day 2 a.m.	_____	_____	_____	_____
day 2 p.m.	_____	_____	_____	_____
day 3 a.m.	_____	_____	_____	_____
day 3 p.m.	_____	_____	_____	_____
day 4 a.m.	_____	_____	_____	_____
day 4 p.m.	_____	_____	_____	_____
day 5 a.m.	_____	_____	_____	_____
day 5 p.m.	_____	_____	_____	_____
day 6 a.m.	_____	_____	_____	_____
day 6 p.m.	_____	_____	_____	_____
day 7 a.m.	_____	_____	_____	_____
day 7 p.m.	_____	_____	_____	_____

STASTICS

chi-square analysis

7. The number of prey of each color removed may differ from one color to the next due solely to chance. Statistical analysis allows one to determine whether the observed differences in feeding are likely due to chance or are due to significantly different feeding behavior by the birds. You can use a Chi-square analysis to make this determination. As shown on page 12, you can compare the actual number of prey removed to the number they would take if they fed randomly. Make a statistical comparison of the first and last days of feeding.

Graph the percent of each color removed.



8. In written reports of this experiment, consider the following questions. (Details about how to prepare lab reports will be provided separately.)

REPORT

questions

   a. Did feeding intensity (total percent prey removed) differ between morning and afternoon?
   b. Did feeding intensity vary with weather? If so, how?
   c. During the last two days of the experiment, did the birds take prey that were mostly one color while leaving behind prey that were mostly another color? If so, why?
   d. Did the feeding pattern of the birds change from the first day to the last two days? If so, why? Would you say that the birds learned something during the course of the experiment?
   e. Does the effectiveness of mimicry (how well protected mimics are from predators) depend on the relative numbers of models and mimics? Were the predictions you made at the beginning of the experiment supported by the results?
   f. What advantage would it be for the signals by which a predator recognizes palatable and noxious prey to be learned rather than innate?

WORKSHEET FOR CHI-SQUARE ANALYSIS

This worksheet may be filled in for whatever time period you wish to use.

null hypothesis H_0: there is no difference in the feeding behavior of the birds on the different colored prey

alternate hypothesis H_A: there is a significant difference in the feeding behavior on the different colored prey

	[yellow]		[green]		[blue]			
Number of prey set out	_____		_____		_____			
Observed number of prey removed (O)	_____	+	_____	+	_____	=	_____	Total no. removed
Expected number of prey removed (E) *	_____		_____		_____			
O – E	_____		_____		_____			
$(O - E)^2$	_____		_____		_____			
$\frac{(O - E)^2}{E}$	_____	+	_____	+	_____	= X^2 (Chi squared) =	_____	

* Calculated for each color as:

$E_{[yellow]}$ = (Total no. removed) x (no. [yellow] set out) / 100

There are three classes of data (the three colors), so there are two degrees of freedom. The probability of the null hypothesis (H_0) being correct can then be evaluated by seeing what range of probabilities is associated with your calculated Chi-squared.

probabilities	0.50	0.25	0.10	0.05	0.025	0.01	0.005	0.001
chi-squared	1.386	2.773	4.605	5.991	7.378	9.210	10.597	13.816

If the chi-squared value is **greater** than 5.991, then the probability of the null hypothesis being correct is **less** than 0.05, so reject the null hypothesis and conclude that the feeding behavior of the birds was significantly different on the different colored prey. If the chi-squared value is 5.991 or less, the probability of the null hypothesis is equal to or greater than 0.05, so accept it and conclude that the difference in feeding you measured was due to chance alone.

REFERENCES

O'Donald, P., and C. Pilecki. 1970. Polymorphic mimicry and natural selection. Evolution 24:395-401.

Pilecki, C., and P. O'Donald. 1971. The effects of predation on artificial mimetic polymorphisms with perfect and imperfect mimics at varying frequencies. Evolution 25:365-370.

Wickler, W. 1968. Mimicry in Plants and Animals. McGraw-Hill, New York, 255 pp.

NOTES TO INSTRUCTORS

GENERAL COMMENTS

1. The best thing about this experiment is that it is fun; students enjoy doing it, remember it, and tell others about it. Students also have input into the experimental design through their assigning of colors to the different degrees of palatability, and, even though it is limited, this direct involvement increases their own learning and interest. Furthermore, the exercise promotes cooperative learning because all members of a lab section contribute in different ways to obtaining the overall results. It is also relatively inexpensive, with most of the disposable items coming from a local supermarket.

2. Advance preparations must be made the first time this experiment is run. Above all, the feeding tray must be constructed and placed in a location where birds normally forage.

wintertime works best

3. This experiment works best when local birds don't have abundant alternative food sources. In the central and northern U.S., it works well in late fall, winter, or early spring, but not as well during early fall, when many seeds and other foods are available naturally. It works best in winter, especially with snow on the ground. That is an advantage for its use, however, because few exercises work well outdoors in winter.

use in a single or multi-section class

4. The entire experiment can be performed by one lab section. In multi-section courses, each lab section could prepare additional prey or, before beginning the experiment, prepare one or two of the "species" of prey ("species" defined by color and palatability) for the entire experiment. Students from all sections can observe the tray and record results. If there are separate wooded areas, a different feeding table could be placed in each, with a different question tested experimentally at each site.

5. Although the experiment was tested for use with local birds just outside a science building in the northeast, it could be modified for use indoors or for other animals that will feed on the dough-like prey. This has not been tested, but could provide an interesting alternative.

vary other factors

6. Different experiments could be performed by varying the other two critical factors in mimicry: the degree of perfection of the mimic (see Pilecki and O'Donald, 1971) and the degree of distastefulness of the models. You could vary the degree of perfection by using different shades of the same color for models and mimics, or you could vary the

degree of distastefulness by adding proportionately more or less quinine sulfate in making the models. If the experiment could run for a longer time, one could switch the colors to see how rapidly the birds adjust to the change. This latter experiment could promote discussion about why warning colors are learned rather than innate.

7. The birds could be conditioned by offering only models for a week or two before introducing the mimics. Prior preference for one color or another could also be measured by using all palatable prey of each color.

BUILDING THE FEEDING TRAY

1. To perform the experiment outdoors as designed, the feeding tray must be constructed in advance. One used successfully for a number of years was constructed as in Figure 2. Window screening was used for the surface of the tray so that rain would drip through, and sections of the tray were separated with thin bands of silicone sealant. A roof could be added to deflect rain and snow.

use a wooded or shrubby area

2. The tray itself may be attached to a post in any accessible wooded or shrubby area. A 2" x 4" post has been left in place year round at one location for an annual running of this experiment. If local birds can be enticed to forage near the laboratory building, the feeding tray could be attached outside the window of the lab itself, thus permitting direct observation from inside the lab. This approach has worked well at one institution.

discouraging squirrels

3. When outside, there is the possibility that animals other than the intended local birds may feed from the tray. They may learn the mimicry system and feed selectively, but that possibility is uncertain, and in feeding, they may stir up or break the prey or knock the tray to the ground. Tree squirrels are the biggest problem. They can be discouraged by placing squirrel-proof baffling on the post. Alternatively, they can be removed from the immediate area by trapping with live traps (e.g., Havahart traps) during the week before the experiment and releasing them somewhere else. For the sake of the squirrels, discouragement is better than removal. Both procedures have been used successfully. One should remember, of course, that squirrels are agile and can jump from nearby vegetation to the feeding tray if shrub or tree branches are near.

attracting birds

4. In tests of the experiment, the birds were initially attracted to the feeding tray by placing sunflower seeds on the tray two weeks prior to the start of the experiment. However, plain prey (uncolored dough)

could be used instead of sunflower seeds to improve the birds' search image for the artificial prey.

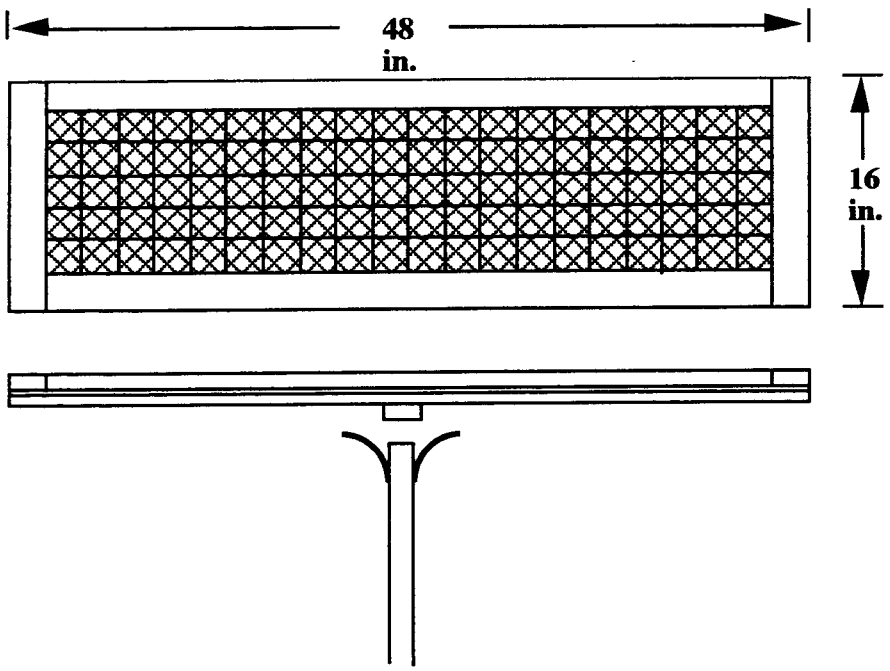


FIGURE 2. feeding table layout

Figure 2. The feeding table. At the edges of the tray, the window screening is sandwiched between strips of 1"x 2" lumber. A cross piece of 1" x 2" lumber on the underside of the tray provides support and a place for attachment to the post using angle brackets.

MAKING DOUGH

1. Students should wear disposable gloves when working with the dough so that the food coloring does not stain their hands and so that they do not add any flavors from their hands to the dough. Keep the flour to lard ratio at 1.6 to 1. The dough will feel sticky because it warms up with handling, but once it has been refrigerated, the consistency will improve. One procedure that has worked successfully for very sticky dough is to place it in a freezer for a few minutes to cool down before being put into the cookie presses. Too little flour leaves a sticky dough that is hard to manipulate. Too much flour produces prey that, once refrigerated, are brittle and break easily.

2. Use white flour only; the colors aren't nearly as bright and distinctive with whole wheat flour.

coloring

3. Once the dough has been divided into three separate portions for coloring, the food coloring should be added to produce distinctive and bright colors. There is no need to produce colors of equal intensity; it is important only that the birds be able to distinguish the three colors readily.

the bitter taste

4. Some prey are made unpalatable by adding quinine sulfate to the dough. It is the quinine that produces the bitter taste, and the form of the quinine is not significant. Though the student instructions specify 0.75% quinine compound by weight, the amount can vary. This amount does produce dough that is bitter, but more or less of the compound could be used. One could redesign the experiment to test the effect of the degree of unpalatability on the rate of learning. Students could taste the dough if you or they wish to compare the tastes of the palatable and unpalatable prey; however, the bitter taste of quinine is strong and lasts a long time, so tastes should be of very small amounts only. For safety reasons, however, we do **not** recommend that students ever ingest lab materials.

the cookie press

5. The best cookie presses to use are those with metallic cylinders (see supply tips below); plastic cylinders break too easily. One can use any of the different design disks that will produce standard diameter spaghetti-like strands. The dough should be squeezed out onto wax paper for ease of manipulation and cutting. It must be emphasized to students that they must take the cookie presses apart completely to clean them thoroughly with soap and water after squeezing out the dough.

6. The prey may be prepared in advance and frozen for later use.

OBSERVATIONS AND RESULTS

1. If possible, have students watch the feeding tray for specific periods of time, especially early in the experiment and late, after the birds have learned the "game." It would be quite instructive to observe the tray when the experiment first begins to see the sequence of colors taken by the birds. Often, the tray is visited by a small flock of chickadees, and they learn the pattern of unpalatability by color surprisingly quickly.

2. With large classes, have two students at a time (morning, noon, afternoon) count leftovers or set out a new array.

alternatives

3. Though students only count the number of each color remaining after an array has been set out for a specified period of time, one could

record the locations of remaining prey to determine whether the birds can distinguish between palatable and unpalatable prey of the same color. The fact that this experiments works well indicates that they do not discriminate between models and mimics when taking a prey from the feeding table; however, one could test their capability to distinguish models and mimics in situ.

4. Because of constant probabilities of each "species" of prey appearing in each square, there is stochastic variation from array to array in the total numbers of palatable and unpalatable prey. That is, actual frequencies vary from one array to the next. Constant probabilities facilitate statistical analysis, but it is unknown whether the changing ratios of colors and palatability from one array to the next have any effect. It is unlikely, but that could form the basis of another experiment.

variation

5. A simple Chi-square analysis sufficient for this experiment is included for comparing the number removed to the number set out. O'Donald & Pilecki (1970) provided a more accurate but slightly more complex Chi-square analysis based on hypergeometric variance. The difference in the two methods is that the simple analysis is based on drawing prey from an infinite population whereas the more accurate method is based on drawing a sample from a finite population, which is what actually takes place in this experiment. Those interested should refer to their paper.

statistics

6. Table 3 on the following page shows actual results. Students count only the total number of each color remaining on the feeding tray, so subtracting the number left from the number set out provides the raw data, which are the number of each color removed by the birds.

example results

	Percent of Prey Removed		
	Yellow	**Green**	**Blue**
day 1 a.m.	100	100	100
p.m.	100	100	97
day 2 a.m.	100	43	45
p.m.	100	100	100
.....			
day 6 a.m.	100	100	30
p.m.	100	96	26
day 7 a.m.	100	32	33
p.m.	100	100	62

TABLE 3. example results:
yellow = palatable
green = mostly mimics
blue = mostly models

SUPPLY TIPS

cookie press - Sawa 2000 is a good model; $28 (or less, 1991) each from The Chef's Catalog (3215 Commercial Ave., Northbrook, IL 60062-1900; telephone 800-338-3232).

quinine sulfate - $21 for 25g from Fisher Scientific (Rochester, NY, customer support center - telephone 716-464-8900; 1991 price), or it may be available in your local drug store.

EXPERIMENTS TO TEACH ECOLOGY FEEDBACK FORM

MIMICRY

Please complete this form after you have used this experiment and mail it to the address given on the reverse side of this page.

1. Was the introduction clear and informative? What changes would you suggest?

2. Was the list of materials complete? Would you suggest any additions or modifications?

3. Was the procedure easy to follow? What changes would you suggest?

4. Were the illustrations and data charts adequate? What others would you include?

5. Were the instructor's notes complete? If you noted any omissions, what were they?

6. What level of students used the experiment? Was it suitable for this level? If not, what changes would you suggest?

7. Did the experiment work? Please explain any problems you had when using the experiment?

8. On a scale of 1-10, with 10 as outstanding and 1 as terrible, how would you rate this experiment? Would you recommend this experiment to others?

9. Was it helpful for this laboratory exericise to have been written for student use rather than as an instructor's guide?

Please mail the completed form to: Dr. Jane M. Beiswenger
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Laramie, WY 82071