ACTIVITY: Evolution by Means of Natural Selection

Recall that in *On the Origin of Species by Means of Natural Selection,* Charles Darwin put forth his idea that evolution proceeded by means of natural selection. This idea can be distilled down into four main tenets:

1. **Overproduction**: Organisms have the capacity to produce large numbers of offspring.
2. **Variation**: These offspring exhibit variable heritable traits.
3. **Competition**: These offspring must compete for limited resources in the environment.
4. **Differential Reproduction**: Those offspring whose physical traits enable them to best exploit resources in the environment will leave more offspring than those less well adapted.

Of the five factors that can change Hardy Weinberg equilibrium, *only natural selection results in a population better adapted for survival in its particular habitat*.

The results of natural selection are everywhere around you. The warning (= **aposematic**) coloration of a stinging bee, a woodpecker's bill, perfectly shaped to extract insects from rotting wood, the camouflaging (= **cryptic**) color of a lizard against tree bark all have resulted from natural selection.

The raw material of these changes, of course, is non-lethal genetic **mutations**. The ancestors of the organisms alive today had mutations that might have made them slightly better "prepared" for survival in a changing environment than other members of their species (their **conspecifics**). Whoever had the most babies won the evolutionary contest!

In real life, natural selection isn't much fun if you're the loser. But today's demonstration should be fun, even though some of us will "go extinct." Today, we will become predators with a variety of different mouthparts, and our prey will be a species of bean that comes in four different colors. Natural selection, sometimes a double-edged sword, will work on both predator and prey. Let's see how it works.

Bean Camouflage vs. Predator Mouthparts

Many predators rely on visual cues to detect prey. Tasty prey items that are less conspicuous than equally tasty members of their population may have a **selective advantage** over their more visible conspecifics.

We will scatter a population of 400 *Beanus gooberensis*, consisting of equal numbers of four color **morphs** of *B. gooberensis*: 100 black, 100 white, 100 lentil, and 100 red. Which color of bean is best at hiding from or escaping predators? That's what we're going to find out.

Before we begin, let's consider...

1. What is your null hypothesis (regarding prey fitness)?

2. What is your alternative hypothesis?

READ DIRECTIONS CAREFULLY BEFORE BEGINNING!

1. You will work in 2 groups of 5. For each group:

2. Dividing the labor among group members, count out 100 individuals of each of the four available bean color morphs.
3. Place all beans together in the container your facilitator provides and shake well to mix them thoroughly.
4. Predators, arm yourselves!
5. The facilitator will scatter beans in a pre-determined area on the floor. On the timer's mark, the predators begin foraging.
6. Predators will have 60 seconds to capture as many beans as possible and place them in their mouths (cups).
7. At the end of the 60 seconds, predators in each group will band together and count how many of each color bean they have captured.
8. When all predator teams are done tabulating their information, the class should share their results and EVERYONE should write the results in Table 1.

PREDATOR RULES:

1. **Predators must pick up prey with their feeding apparatus only. No helping with fingers or other objects, including the cups!**
2. **Predators may not remove prey from a fellow predator's mouth (yuck!), but they may feel free to dash in and fight for any prey being pursued by another predator. It's a jungle out there. Hungry predators are not kind to strangers.**

Ready? On your mark. Get set. GO!!! (Once the first round of bloody carnage is over, all groups return to the lab to count and digest their prey.) Use Table 1 to record the data for each bean color and predator type.

Step One: How many beans have survived to reproduce?

Now go to PAGE 5 and use Table 1 to compile your data. You'll use this table for all four generations, so try to keep it neat and readable as you add more data.

1. Each group of predators (forks, etc.) should provide the number of each bean color caught. **Everyone in the group should write these numbers in Table 1**.

- Count the number of *each color bean* killed by *each predator*, and enter in Table 1.
- Subtract the number killed from 100 (your starting population) to get the number of survivors. Enter these numbers in the bottom row for each generation in the table.

2. To calculate how many beans survived to reproduce, go to page 5 and use Table 1. Survivors will be the total of each color minus the number killed of each color.

3. **Finally, to calculate the number of new baby beans ("recruits") in each next generation, go to page 7 and use the calculation sheets for, respectively, Generation II, III and IV.**

4. For each bean color, **calculate the number of new beans to add to the population** with the formula shown below and in the work boxes on Page 7. The general formula is:

$$\frac{\text{\# of prey color survivors}}{\text{total \# of survivors (all colors)}} \times \text{total \# of prey killed (all colors)} = \text{\#of prey color for next generation}$$

This is an index of how many beans were left behind in the population to have babies.

Step Two: How many predators have survived to reproduce?

Natural Selection. It's a sharp sword, and it cuts both ways. Predators, too, have experienced differential success in this game, and that means differential reproduction. Some feeding structures are better suited for capturing beans than others. However, we will do this simply: **The predator that captures the fewest beans, dies. And a new predator of the most successful type (the one with the most captures) is born for the next round.**

On page 12, you'll find a table for the predator population.

Round Two, and Beyond!

After you have determined the composition of the next generation of predators and prey, count the correct number of new bean **recruits** to be added to the existing population. The group leader will scatter prey on the lawn in the same habitat we hunted before, and the predators will set upon them once more for 90 seconds.

Repeat the calculations for predators and prey as above, and do as many generations as time permits. Use Table 1 to record your data. Use the extra calculation sheets provided for prey for each Generation (pp 7 – 12).

REMEMBER THAT THE NUMBER OF BEANS OF EACH COLOR WILL CHANGE IN EACH GENERATION, BECAUSE EACH COLOR HAS DIFFERENT MORTALITY AND SURVIVORSHIP. When you add your **new recruits** to the population, add it to the **survivors** of the previous generation to get the correct **total number of beans of each color** for your calculations. Obviously, you won't have 100 of each color in each generation, because some of the beans are escaping better than others. But there should be 400 total beans in each generation; only the color proportions should change (how does this square with real life?)

Graphing Your Data

Once you have completed several generations, plot the results of prey population changes on a graph. Use a line graph.

What do the graphs tell you about the prey, and their relative fitness compared to their conspecifics (i.e., members of their own species)?

THOUGHT QUESTIONS

1. Which color prey seem to be the best adapted to this environment and its predators? Which is the least adapted? Explain.

2. Can you think of any factors besides bean color which could have affected the bean survival? Do you think that only one phenotypic character is primarily responsible for survival in a complex environment? Why or why not?

3. Did any prey type become extinct? Why or why not? If none went extinct, would you predict that any might go extinct over more generations? Which ones and why?

4. Did the experimental results support or refute your null hypothesis? Can you devise a new hypothesis in light of your results? What further tests might you perform on these populations?

5. The last page explains how to calculate the relative fitness of your prey. Complete Table 4, listing the relative fitness of the beans over 4 generations, and on average. Graph the relative fitnesses of the beans over time. Which bean type had the average highest relative fitness? Did this change over the generations? Why might the relative fitness of genetic variants change over time?

Table 1. Changes in Bean Prey Population

Starting Generation:

prey generation	black	white	lentils	red	TOTAL
0: total	100	100	100	100	400

Generation I: After the first round of hunting, fill in...

prey generation	black	white	lentils	red	TOTAL
a: # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					400

Use the work boxes starting on page 6 to calculate **c**., the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation II.

Generation II: After the second round of hunting, fill in...

prey generation	black	white	lentils	red	TOTAL
a: # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					400

Use the work boxes to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation III.

Generation III: After the third round of hunting, fill in...

prey generation	black	white	lentils	red	TOTAL
a. # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					400

Use the work boxes to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation IV.

Generation IV: After the fourth round of hunting, fill in...

prey generation	black	white	lentils	red	TOTAL
a. # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					400

Use the work boxes to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation V.

Generation V: After the fifth round of hunting, fill in...

prey generation	black	white	lentils	red	TOTAL
a. # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					400

Use the work boxes to calculate the # of new baby beans (recruits) to add to your surviving population in the grass to get your final number. This will be Generation VI.

GENERATION I: CALCULATING THE # OF NEW BABY BEANS

Use the spaces below to calculate the number of each color bean in the Generation II.

a. black beans:

# of black survivors x total # of beans killed = #of new black beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **black** beans here:

( ) x ( ) = ______
( ) ("recruits")

b. white beans:

# of white survivors x total # of beans killed = #of new white beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **white** beans here:

( ) x ( ) = ______
( ) ("recruits")

c. lentils:

# of lentils survivors x total # of beans killed = #of new lentils added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **lentils** here:

( ) x ( ) = ______
( ) ("recruits")

d. red beans:

# of red survivors x total # of beans killed = #of new red beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **red** beans here:

( ) x ( ) = ______
( ) ("recruits")

Once the numbers of new baby beans of each color have been calculated, volunteers will count up the correct number of each color, and add them to the Baby Bean Bin. These will be taken outside and added to the surviving bean population for the next round of predation.

GENERATION II: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

# of black survivors x total # of beans killed = #of new black beans added
total # of survivors (all colors) to the population
(all colors)

Do your calculation for the **black** beans here:

( ) x ( ) = ____________
( ) ("recruits")

b. white beans:

# of white survivors x total # of beans killed = #of new white beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **white** beans here:

( ) x ( ) = ____________
( ) ("recruits")

c. lentils:

# of lentils survivors x total # of beans killed = #of new lentils added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **lentils** here:

( ) x ( ) = ____________
( ) ("recruits")

d. red beans:

# of red survivors x total # of beans killed = #of new red beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **red** beans here:

( ) x ( ) = ____________
( ) ("recruits")

GENERATION III: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

# of black survivors x total # of beans killed = #of new black beans added
total # of survivors (all colors) to the population
(all colors)

Do your calculation for the **black** beans here:

(____________) x ( ) = ____________________
( ) ("recruits")

b. white beans:

# of white survivors x total # of beans killed = #of new white beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **white** beans here:

(____________) x ( ) = ____________________
( ) ("recruits")

c. lentils:

# of lentils survivors x total # of beans killed = #of new lentils added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **lentils** here:

(____________) x ( ) = ____________________
( ) ("recruits")

d. red beans:

# of red survivors x total # of beans killed = #of new red beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **red** beans here:

(____________) x ( ) = ____________________
( ) ("recruits")

GENERATION IV: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

# of black survivors x total # of beans killed = #of new black beans added
total # of survivors (all colors) to the population
(all colors)

Do your calculation for the **black** beans here:

(____________) x ( ) = ____________________
( ) ("recruits")

b. white beans:

# of white survivors x total # of beans killed = #of new white beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **white** beans here:

( ) x ( ) =

( ) ("recruits")

c. lentils:

\# of lentils survivors x total # of beans killed = #of new lentils added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **lentils** here:

( ) x ( ) = ________________
( ) ("recruits")

d. red beans:

\# of red survivors x total # of beans killed = #of new red beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **red** beans here:

( ) x ( ) = ________________
( ) ("recruits")

GENERATION V: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

\# of black survivors x total # of beans killed = #of new black beans added
total # of survivors (all colors) to the population
(all colors)

Do your calculation for the **black** beans here:

( ) x ( ) = ________________
( ) ("recruits")

b. white beans:

\# of white survivors x total # of beans killed = #of new white beans added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **white** beans here:

( ) x ( ) = ________________
( ) ("recruits")

c. lentils:

\# of lentils survivors x total # of beans killed = #of new lentils added
total # of survivors (all colors) to the population ("recruits")
(all colors)

Do your calculation for the **lentils** here:

( ) x ( ) = ________________
( ) ("recruits")

d. red beans:

$\frac{\text{\# of red survivors}}{\text{total \# of survivors (all colors)}}$ x total # of beans killed (all colors) = #of new red beans added to the population ("recruits")

Do your calculation for the **red** beans here:

$\frac{(\quad\quad)}{(\quad\quad)}$ x ( ) = ________________ ("recruits")

Table 4: Relative Fitness (w_i) of prey

	Black	Red	Lentils	White
Gen 1-2				
Gen 2-3				
Gen 3-4				
Avg				

Calculating Fitness

Suppose we have the following example. We begin with 100 beans in generation 1: 25 black, 25 red, 25 lentils and 25 white. After a generation, there were the following survivors: 20 black, 18 red, 24 lentils, 25 white. Now, as one measure of **absolute fitness** we can use the probability of survival. We'll call this fitness measure W, so that:

W = (# of survivors) / (initial #)

We then have:

W_{black} = 20/25 = 0.80 (or, 80% of black beans survive)
W_{red} = 18/25 = 0.72 (or, 72% of red beans survive)
$W_{lentils}$ = 22/25 = 0.88 (or 88% of lentils peas survive)
W_{white} = 24/25 = 0.96 (or 100% of pinto beans survive)

Biologists typically do not use absolute fitness; instead, we calculate something called **relative fitness**. This measure, symbolized w, is given by: w_i = (absolute fitness of trait *i*) / (maximum absolute fitness in population)

In our predator population, the maximum absolute fitness is 0.96, for wnite beans, and so we have:

W_{black} = 0.8/0.96 = 0.83
W_{red} = 0.72/0.96 = 0.75
$W_{lentils}$ = 0.88/0.96 = 0.92
W_{white} = 0.96/0.96 = 1.0

What this says is that black beans have 83% of the fitness of white beans **in this environment**, while red beans have only 75% of a pinto beans' fitness.