LAB 17 – Natural Selection Simulation

Introduction:

This game was invented by G. Ledyard Stebbins, a pioneer in the evolution of plants. It has been since adapted by Kim Foglia of Division High School and now utilized here. The purpose of the game is to illustrate the basic principles and some of the general effects of evolution by natural selection. Also, you should gain from it some understanding of the process of evolutionary adaptation.

Natural selection acts at the level of **individuals**. It is the individual organism that lives or dies, reproduces or fails to reproduce. **Populations evolve**; that is, the characteristics of the group of organisms change over time. In general, the physical characteristics of an individual are fixed throughout its lifetime. An individual **cannot** change in its lifetime and then pass new characteristics to their offspring. Because some individuals live and some die, the average characteristics of populations change over time.

'Changes in the characteristics of the individuals in a population over time' is one useful definition of evolution (there are others). Evolution by natural selection, as first proposed by Charles Darwin, includes four conditions:

1. **Variation**: There are significant differences between the individuals in populations. Furthermore, it is generally assumed that these variations are random (*i.e.* not purposeful). In this simulation, random variation is modeled by different colored foam dots. For the purposes of this simulation, these dots are assumed to be different forms of individuals of the *same* species, for instance a population of butterflies.
2. **Inheritance**: The variations that exist within the population must be inheritable from parents to offspring, that is, they can be passed on in genes. Darwin clearly recognized that this was the case, although he did not know about genes or DNA and did not originally propose a genetic method by which this could occur. In this simulation, inheritance is "perfect" – that is, offspring inherit the exact form of their parents, for instance red butterflies only reproduce red butterflies.
3. **Overpopulation**: As a consequence of reading Malthus's *Essay on the Principle of Population*, Darwin realized that in natural populations more offspring are born than can possibly live to reproduce. In this simulation, overpopulation is modeled by having only part of each generation's offspring survive to be able to reproduce.
4. **Differential Survival and Reproduction**: Given the three conditions described above, certain individuals will survive and reproduce more often than others, and such individuals (and their offspring) will therefore become proportionally more common over time. This, in a nutshell, is evolution by natural selection.

In natural environments, one of the most noticeable forms of natural selection is **predation**. Predators eat other organisms, while prey are eaten by them. One of the most important investigations into the theory of evolution by natural selection was carried out by H.B.D. Kettlewell and his colleagues in the 1950s. Kettlewell studied the effects of bird predation and air pollution on the genetic and morphological traits of Peppered moth (*Biston betularia*) populations in southern England.

In our natural selection game (actually a real-time simulation), we will study a closely related phenomenon — the evolution of **protective coloration**. Many animals, especially insects, are very well-camouflaged against visual detection by predators, especially birds. In some cases the insects **mimic** some part of their habitat, such as a leaf. The question under investigation in this game is, how do mimicry and protective coloration evolve?

How To Play The Game

In this game/simulation, foam dots of different colors represent butterflies. The different colors represent different color variations *within **one** species of butterfly*. These different color variations are the result of purely random genetic mutations and recombination within this single species. To model the random character of these variations, we will begin with equal numbers of each color dot at the start of the game. It is assumed that the different colors are inherited genetically.

Step 1: One person should be designated as the first predator. This person should not be allowed to see what goes on during the following steps, in order that her/his "predation" be unbiased.

Step 2: Each group will begin with a different, colored foam "environment." One person in each group should count out four dots of each color — this is the starting population for your environment — Generation #1. This same person should then randomly scatter these dots on the cloth environment. Since there are five colors, there will be a total of twenty dots on the environment to start with. This is the **carrying capacity** of your environment.

Step 3: The predator should now pick up ten dots as quickly as possible, one dot at a time. Also, it is important that the predator *break eye contact with the ground after each pick* — ***be sure to pick the very first dot that you see!*** After all, time is energy (you're flying, remember!), and so you can't afford to waste either time or energy by being too picky. Set your "eaten" dots aside, so that they won't accidentally be counted as surviving dots.

Step 4: Now collect your surviving dots (butterflies) by gently shaking the foam mat out onto the table (it works best to pour the dots out). There should be ten surviving dots.

Step 5: Each surviving dot now reproduces. For each surviving dot, add **one** dot of the same color from your reserve — your dots have now reproduced! This is the second generation; there should now be twenty dots ready to go into your environment again.

Notice that there may not necessarily be the same number of each color any more — natural selection has been at work in your population of individuals! Before you scatter the dots in the environment for the second time, record the frequencies of each color type in the table, below. Notice that each dot is worth five percent.

Step 6: Randomly scatter the new generation of twenty dots in your environment and repeat the above steps using a new predator. Continue until you have completed five generations, recording the data in the tables below. This is now your "raw data".

DATA COLLECTION – ________________ – colored background

1. Indicate the color background above and record your raw data in the table below:

	number of butterflies entering generation					
color variants	**1**	**2**	**3**	**4**	**5**	**6 (final)**
red	**4**					
yellow	**4**					
blue	**4**					
green	**4**					
white	**4**					
TOTALS	**20**	**20**	**20**	**20**	**20**	**20**

2. Calculate the frequency (percentages) of each of the color variants from your data and record in the data table below:

	frequency of color variants entering population					
color variants	**1**	**2**	**3**	**4**	**5**	**6 (final)**
red	**20%**					
yellow	**20%**					
blue	**20%**					
green	**20%**					
white	**20%**					
TOTALS	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

3. Graph your calculated frequency (percentages) of each 'species' using a multiple-line graph (completely labeled and titled) on the graph paper – page 8 – **AND** another one with Excel.

Questions:

1. Describe the "environment" that you used in this simulation. How did it vary from group to group?

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2. How many butterflies of each color variant did you start with in Generation #1?__________

   What was the frequency of each color variant at the start of Generation #1? ____________

3. Did you end up with the same number of each color variant entering Generation #6?

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4. a. Which color variant was the ***most fit*** in your environment? _________________________

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   b. How many of this color variant did you start with in Generation #1? _________________

   c. What was the frequency of this color variant at the start of Generation #1? ___________

   d. How many of this color variant did you end up with in Generation #6? _______________

   e. What was the frequency of this color variant at the start of Generation #6? ___________

   f. Suggest a possible explanation of why this color variant was more fit in this environment.

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5. a. Which color variant was the ***least fit*** in your environment? _______________________

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b. How many of this color variant did you start with in Generation #1? _________________

c. What was the frequency of this color variant at the start of Generation #1? ___________

d. How many of this color variant did you end up with in Generation #6? _______________

e. What was the frequency of this color variant at the start of Generation #6? ___________

f. Suggest a possible explanation of why this color variant was less fit in this environment.

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6. Scientific investigations may include starting assumptions and built-in biases that cause the experiment to less accurately model nature. Were there any starting assumptions for this experiment that you had? Can you detect any ways that the experimenter (you!) may have been influenced by any biases that might have altered the results.

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7. <u>Separate from your data in this lab</u>, consider the following independent "thought experiments" in natural selection—what outcome might you expect under the following conditions described below.

a. If the color differences were less distinct (ex. all butterflies were various shades of green – lime, olive, forest green, etc. – instead of strikingly different colors), would you expect the same results? Why or why not?

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b. What if the red butterflies made the predator very ill (but it wouldn't kill it); would you expect this to affect the results? Why or why not?

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c. What assumptions must you make about the *predator* to answer the question above (7b)?

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d. What would you expect to happen if the red butterflies made the predator very ill, but a new color variant, say reddish-orange, did not? **Explain your answer in terms of frequency of the variants in the population**.

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e. What trait would be strongly selected for in the *predator* population in the situation proposed above (Question 7d)?

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8. What do the results of this experiment tell you about the mechanisms that drive evolution by natural selection? Do you see evidence of "purpose" in evolution by natural selection (*i.e.* did certain color variants **choose** to be the more successful color "on purpose")? Do you see evidence of "design" in evolution by natural selection (*i.e.* was there a "plan" or a pre-planned "design" that decided which butterfly color variant would survive)? Explain.