Evolution: The Darwinian Revolutions

BIOEE 2070 / HIST 2870 / STS 2871

A Natural Selection Game

DAY & DATE: Monday 25 June 2012

NAME: ______________________________ **DATE:** ______________________________

This game was invented by G. Ledyard Stebbins, a pioneer in evolutionary theory as applied to plants. 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, and perhaps some insight into the role of purpose in evolution by natural selection.

Natural selection acts at the level of **individuals**. It is the individual organism that lives or dies, reproduces or fails to reproduce. **Populations evolve** — the characteristics of the organisms of which they are composed change over time. The physical characteristics of an individual are generally fixed throughout its lifetime, whereas 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, as we will see).

Evolution by natural selection, as first proposed by Charles Darwin, is the result of three processes:

1) Variation: There must be significant differences between the individuals in populations undergoing natural selection. Furthermore, it is generally assumed that these variations are **random** (*i.e.* not purposeful). In this simulation, random variation is modeled by different colored paper dots. For the purposes of this simulation, these are assumed to be different forms of individuals of the *same* species.

2) Inheritance: The variations that exist within the population must be heritable from parents to offspring. Darwin clearly recognized that this was the case, although he did not originally propose a genetic mechanism by which this could occur. In this simulation, inheritance is "perfect" – that is, offspring inherit the exact form of their parents.

3) Fecundity: 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 half of each generation's offspring survive until they can reproduce.

If these three processes operate as specified, then the following outcome is virtually inescapable:

4) Unequal Non-Random Survival and Reproduction: Some 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 first investigations into the theory of evolution by natural selection by 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 pepper moth populations in southern England. The scientific name for the pepper moth is *Biston betularia*. You can read more about the pepper moth and industrial melanism online at: http://en.wikipedia.org/wiki/Pepper_moth

In our natural selection game (actually a real-time simulation), we will study the dynamics of a closely related phenomenon - the evolution of **protective coloration** (sometimes called "crypsis"). 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, paper 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 of 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 cloth "environment." One person in each group should count out four dots of each color - this is the starting population for your environment. 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: Gently shake the cloth 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".

Results

As each group finishes collecting their data, the results should be tallied. You should then copy the results for all of the groups into the tables below:

Color Morph	Frequency Per Generation				
Red					
Yellow					
Green					
Blue					
White					

Table ____: ________Environment

Color Morph	Frequency Per Generation				
Red					
Yellow					
Green					
Blue					
White					

Table ____: ________Environment

Color Morph	Frequency Per Generation				
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Discussion

Now it is time to analyze and interpret your results. Consider the following questions:

1) What were your results and what conclusions can you draw from them? Which color morph succeeded and why? Which failed? Why?

2) All scientific investigations include starting assumptions and built-in biases. What were the starting assumptions for this experiment, and can you detect any bias that might have influenced the results?

3) Consider the following "thought experiments" in natural selection - what outcomes might you expect under the conditions described?

- If the color differences were less distinct, would you expect the same results? Why or why not?

- What if the red dots made the predator very ill? What assumptions must you make about the predator to answer this question?

- What if the red dots made the predator very ill, but a new color morph, say reddish-orange, did not? What would happen to red dots? To reddish-orange dots? Why?

- Which has the greater effect on adaptation - the organism or its environment?

4) Do you think the same processes occur in nature? Why or why not?

5) What do the results of this experiment tell you about the concept of evolution by natural selection? In particular, do these results support the conclusion that **purpose** plays a role in evolution by natural selection (*i.e.* did certain color morphs succeed and others fail "on purpose?")

- For example, are the white dots that survive in the blue environment white "in order to survive being eaten", and therefore "to ensure the survival of white dots?"

6) What did you personally learn from this exercise?

Please turn in the completed exercise at the next lecture – thanks!