Name ____________________________ **Period** _________

Regents Biology **Date** ______________________

LAB _____. NATURAL SELECTION

This game was invented by G. Ledyard Stebbins, a pioneer in the evolution of plants. The purpose of the game is to illustrate the basic principles and some of the general effects of **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 because of its characteristics. When more individuals with a particular trait survive then the overall population will change over time — it will be made up of more and more individuals with that successful characteristic. This change over time in the population is **evolution**.

For example, let's imagine that it is a dry year and food is scarce. There is a flock of birds. The birds in the flock that have the larger, sturdy beaks are the only ones that can eat what are usually hard-to-crack seeds. So those large-beak birds get more food than the smaller beak birds and they therefore survive more. Since they survive more they also get to reproduce more — lay more eggs and have more babies. Now more of the birds in the next generation will inherit the large beak from their parents. So the next generation flock will be made up of more large-beak birds. If this drought stayed for many years then over time this bird species may end up being made of mostly large-beak birds and very few small beak birds. We would therefore say that this flock of birds had evolved over time.

Evolution by natural selection, as first proposed by Charles Darwin, includes four conditions:

1. **Variation**: Variation means that there are differences between the individuals in a population. In this lab, variation is simulated by different colored paper dots. For the purposes of this lab, these dots are assumed to be different colored butterflies of the *same* species — a species that has a range of colors in one population living in an area together.

2. **Inheritance**: The variations that exist within the population must be inheritable from parents to offspring. The characteristics can be passed on in genes. Darwin clearly recognized that this was the case, although he did not know about genes or DNA. In this lab, inheritance is "true breeding" — that is, offspring inherit the exact color of their parents, for instance red butterflies only reproduce red butterflies.

3. **Overproduction**: As a result of reading a famous essay of his time — *Essay on the Principle of Population* by Malthus — 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. The rest of the individuals are eaten by a predator.

4. **Differential Survival and Reproduction**: Given the three conditions described above, certain individuals will survive and reproduce more often than others, and these individuals and their offspring (the ones with the successful traits) will therefore become 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. In our natural selection "game" (actually a simulation), we will study a closely related phenomenon — the evolution of **protective coloration**. Many animals, especially insects, are very well camouflaged against being seen or found by their 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?

DIRECTIONS: 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*. We will begin with equal numbers of each color butterfly (each color dot) at the start of the game. It is assumed that the different colors are inherited genetically.

Step 1: Divide the class into two-person teams. Each team will begin with a different, colored cloth "environment" (~16” x 16” square). One person should be designated as the first “Butterfly Predator”. The Butterfly Predator should not be allowed to see what goes on in Step 2, in order that her/his "predation" remain unbiased. The other team member sets up the environment of butterflies.

Step 2: The other team member should count out **four butterflies (dots)** of each color — this is the starting population for your environment — Generation #1. Record that in the data table. This same person should then randomly scatter these butterflies on the cloth environment. Since there are **five colors**, there will be a total of **twenty butterflies** in the environment to start with. This is the maximum population of butterflies your environment can support — it’s the **carrying capacity** of your environment.

Step 3: The Butterfly Predator should now capture ten butterflies by picking up **10 dots** as quickly as possible, **one dot at a time**. Also, it is important that the Butterfly Predator *break eye contact with the ground after each pick* (look away from the cloth and then down again before each hunt). ***Be sure to pick the very first butterfly that you see!*** After all, time is energy (you're hunting, remember!), and so you can't afford to waste either time or energy by being too picky. Put your "eaten" butterflies (dots) away; they have been removed from the population and do not get to reproduce.

Step 4: Now collect your surviving butterflies (dots) from the cloth. Be sure to get all of them. There must be **10 surviving butterflies**.

Step 5: Each surviving butterfly (dot) now reproduces. For each surviving butterfly, add **one dot of the same color** from your reserve — your butterflies have now reproduced! So now you will have 20 butterflies again. This is Generation #2. Count your butterflies and record the number of each color variant for Generation #2 *only* in the Butterfly Predator’s data table.

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!

Step 6: For all the next rounds (Generations #2 to #6), the Butterfly Predator remains the same person. The other team member should again randomly scatter the new generation of 20 butterflies in the environment and repeat the above steps. Continue until you have completed all generations. Record the data *only* in the Butterfly Predator’s data table.

Step 7: Team members should switch roles and complete the new Butterfly Predator’s data table. In this way, you have replicated your experiment with a different predator but using the same environment.

DATA COLLECTION

1. After you have chosen your "environment" cloth, write down your **prediction** of which color morph of this species of butterfly will better be able to survive in this environment ____________________________

2. Record your **raw data** in the table below:

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

3. Calculate the **percentages** of each butterfly color and record in the table below:

	percentage of color variants entering generation					
Color variants	**1**	**2**	**3**	**4**	**5**	**6 (final)**
red						
yellow						
blue						
green						
white						
TOTALS	**100**	**100**	**100**	**100**	**100**	**100**

4. Graph your calculated percentages using a **bar graph/histogram**.

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SUMMARY QUESTIONS

1. Describe the "environment" that you used in this simulation.

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

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

3. Did the number of each color stay the same from generation to generation? Explain.

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4. a. Which color was the ***most fit*** in this environment? _______________________________

   b. How did you determine that? ____

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   c. How many of this color did you start with in Generation #1? ________________________

   d. What was the frequency of this color at the start of Generation #1? __________________

   e. How many of this color did you end up with in Generation #6? ______________________

   f. What was the frequency of this color at the start of Generation #6? __________________

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

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5. a. Which color was the ***least fit*** in this environment? ________________________________

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   b. How did you determine that? ____

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c. How many of this color did you start with in Generation #1? ______________________

d. What was the frequency of this color at the start of Generation #1? _________________

e. How many of this color did you end up with in Generation #6? ____________________

f. What was the frequency of this color at the start of Generation #6? _________________

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

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6. **Separate from your specific environment used in this lab**, consider the following "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 only shades of reds and oranges), would you expect similar results? Explain what you would expect and why.

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b. What if you had a population with all 5 colors again, but the red butterflies made the predator very ill; would you expect similar results? Explain what you would expect and why.

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c. What assumptions must you make about the predator's abilities for your prediction to come about in the question above (7b)?

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d. What if the red butterflies made the predator very ill and it learned to stay away from them, and there also was a new group of butterflies very similar in color (a close red-orange color). What would happen to the red-orange butterflies? Explain your answer.

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e. Over the long term, what trait (ability) could be strongly selected for in the **predator** population in the situation of similar color variants proposed above (7d)?

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f. In 7(e) you identified a trait (ability) that would strongly benefit the **predator** population. Does that mean the population ***will*** evolve that trait, since it is a "need" they have.

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7. Consider the results in this lab. Did any of the butterflies survive because they **chose** to be the more fit color? Did any supernatural power **design** the surviving butterflies to be more fit? What did you learn about how evolution works from this lab?

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8. Don't forget to graph your calculated percentages using a **bar graph/histogram**.