Name _____   Period _____

AP Biology   Date _____

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 particular traits survive then the overall population will change over time — it will be made up of more and more individuals with those successful characteristics. This change over time in the population is **evolution**.

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

1. **Variation**: There are significant differences between the individuals in populations. In this simulation, variation is modeled by different colored paper 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 that has a range of colors.

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 and did not originally propose a genetic method by which this could occur. In this simulation, inheritance is "true breeding" — that is, offspring inherit the exact form 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 (with the successful traits) 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 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, 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 genetic recombination within this single species. To model the random character of these variations, 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-#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:

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

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

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

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

SUMMARY QUESTIONS

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

    _____

    _____

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

    What was the <u>frequency</u> of each color at the start of Generation #1?_____

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

    _____

    _____

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

    b. How did you determine that? _____

       _____

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

    d. What was the <u>frequency</u> 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 <u>frequency</u> of this color at the start of Generation #6? _____

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

       _____

       _____

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

       _____

    b. How did you determine that? _____

       _____

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

d. What was the <u>frequency</u> 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 <u>frequency</u> of this color at the start of Generation #6? _____

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

_____

_____

_____

6. **<u>Separate from your specific environment used in this lab</u>**, 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)?

_____

_____

_____

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 frequencies using a **bar graph/histogram**.