Name: ____________________
Date : ___________ Per. : ___

Natural Selection Introduction: The Case of the Peppered Moth

Background Information:

• Prior to the Industrial Revolution in England (pre-1740), the peppered moth was found almost always in its light body colored with black spots. The moth would spend daylight hours on trees covered with light colored lichen. (Since they blended in with the lichen on the trees, they had perfect camouflage against predatory birds.) There were a few dark colored moths in the population, but their occurrence was rare.

• The body color of moths is determined by a single gene; the dark version (allele) is dominant (A) and the light allele (a) is recessive: The results of random mating of two heterozygotes (Aa x Aa) is represented by the Punnett Square below:

	A	**a**
A	**A A**	**A a**
a	**A a**	**a a**

• The **genotypes of the offspring** are: AA = homozygous dominant = 1/4
Aa = heterozygous = 1/2
aa = homozygous recessive = 1/4

• The **phenotypes of the offspring** are : AA, and Aa = dark colored moths
aa = light colored moths

1. Which moths have a distinct disadvantage in a **pollution – free environment**? ________

For this reason, the frequency for the dark allele (A) was very low in the population. They were present in the population because of spontaneous mutations from light to dark alleles.

• By 1819, the proportion of dark moths increased in the population significantly. Researchers found that the pollution caused by sulfur dioxide from factories was killing the light colored lichens on the trees. (sulfur dioxide is a by-product of coal burning during the Industrial Revolution). Without the light colored background of the trees to protect them from the predatory birds, the light colored moths (aa) were more visible and lost their selective advantage to the dark colored moths.

• By 1848, the dark colored moths (Aa and AA) had increased from 1% to 90% .
The dark colored trees (without the light lichen) served to protect these moths.
Now the dark allele (A) could survive in the population.

• The researchers **G.H. Hardy and W. Weinberg** developed a mathematical expression to describe the equilibrium of the genotype frequencies which occur under random sexual mating of organisms of large population size, no mutation, no migration, and no natural selection. ($p^2 + 2pq + q^2 = 1$) where p^2 is the frequency of AA , 2pq is the frequency of Aa, and q^2 is the frequency of aa.

2. If there is NO pollution, what do you predict will happen to the population equilibrium as stated by the Hardy- Weinberg theory? (Will the population stay at equilibrium?)

3. If the pollution level becomes high, what do you think will happen to the population as light lichen on trees is killed?

Predict what would happen to the :

a. genotype

‘AA’ genotype: ____

‘Aa’ genotype: ____

‘aa’ genotype: ____

b. phenotype :

Dark phenotype moths (AA, and Aa genotypes): ___________________________________

Light phenotype moths (only aa genotypes): ______________________________________

c. allele frequency: (frequency is calculated by : the # observed / total number in population)

‘A’ allele frequency in the population: ____

‘a’ allele frequency in the population: ____

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Open the STELLA model named moth.stm and use the scroll bar on the side to familiarize yourself with the items on the screen. By changing the amount of pollution, we can simulate the living conditions of the peppered moth in England before and after the Industrial Revolution.

- Graph 1 will show you the phenotype frequencies : DARK and LIGHT moths
- Graph 2 will show you the genotype frequencies : AA, Aa, and aa
- Graph 3 will show you the allele frequencies : A and a

1. If we start with a total moth population of 1000 under the idealized Hardy-Weinberg conditions, how many of each genotype of moth should there be?

AA mothies = ________________Aa mothlets = _____________aa moths = _____________

2. At the top of the screen is a pollution slider. Move the slider bar to the 0.0 setting. This indicates the pre-Industrial Revolution level of pollution.

Which phenotype (dark or light) is more fit in a pollution-free environment? ________________

Which genotype (AA, Aa, aa) is most fit in a pollution-free environment? ________________

3. Click on the RUN button. The graphs will show you the changes that would occur over a 200 year span with no pollution. Sketch below the phenotype, the genotype, and the allele frequency graphs that result. <u>Be sure to label the axes and each curve</u>.

Phenotype Frequency Genotype Frequency Allele Frequency

4. Describe and interpret the curves in each graph. What is causing the changes you see?

Phenotype Frequency:

Genotype Frequency:

Allele Frequency:

5. According to the numerical displays, at the end of 200 years with minimum pollution:

frequency of A = ______________ frequency of a = _________________

6. Click on the pollution slider and change the pollution level to 1 (the maximum pollution level).

Which phenotype should now be the most fit? _________________________

Which genotype(s) should now be most fit? _________________________

7. RUN the model. Sketch the phenotype, genotype and allele frequency graphs below. Label!!!

Phenotype Frequency Genotype Frequency Allele Frequency

8. Describe and interpret the curves in each graph. What is causing the changes you see?

Phenotype Frequency:

Genotype Frequency:

Allele Frequency:

9. According to the numerical displays, at the end of 200 years with maximum pollution:

frequency of A = __________________frequency of a = _______________

10. When pollution = 0 in the first simulation, the dark moths were eliminated from the population after 200 years. When pollution = 1, there were still some light colored moths remaining in the population after 200 years, even though the light color was just as harmful in the second simulation as the dark color was in the first simulation. What is allowing the light colored moths to persist for this long?

11. Using your graphs and answers to the questions about the graphs, write a complete conclusion paragraph that describes what happened to the moth population as a result of the Industrial Revolution in England.

Use the following vocabulary words in your conclusion: (check off the words as you use them).

___ allele	___ recessive	___ natural selection
___ genotype	___ genotype frequencies	___ spontaneous gene mutation
___ phenotype	___ phenotype frequencies	___ population equilibrium
___ dominant	___ allele frequencies	___ Hardy-Weinberg theory

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Extension: A variable pollution rate

We will run the model with a changing pollution rate, which we can define graphically (as opposed to a mathematically).

- Use the dynamite to blow up the pollution slider.
- Click on the triangle in the upper left-hand corner of the screen to view the model.
- Click on and open the pollution converter, and then select and click on the TIME function in the Built-ins list. (You must first delete the value in the equation box.)
- Now click on Become Graph to get to the graphical function. Notice that the X axis is TIME and the Y axis is pollution.
- Change the number at the top of the Y axis to 1.0 to restrict the range of pollution to between 0 and 1.
- Then modify the X axis to range from 0 to 200, representing a time span of 200 years.
- Next, using your mouse, draw a graph that starts off at 1 (maximum pollution) and drops rapidly to 0 (no pollution) halfway across the graph (i.e. TIME ~100).
- Click OK to close the window.
- Click on the upper triangle in the upper left-hand corner of the screen to return to the front page.
- Click on the Run button.

ANSWER THESE QUESTIONS

1. Sketch the graphs that reflect a drop in pollution near year 100. Be sure to label the axes and each curve.

Phenotype Frequency Genotype Frequency Allele Frequency

2. Describe and interpret the curves in each graph. What is causing the changes you see?

Phenotype Frequency:

Genotype Frequency:

Allele Frequency:

- Now vary the timing of the drop in pollution by shifting the position of the drop on the X axis.
- Note how the timing affects the dynamics of the different genotypes.
- You do not need to sketch your graphs for these variations.

3. What would you expect to happen (in terms of genotype frequencies) if pollution levels fluctuated widely? Check out your hypothesis by playing with the pollution function (add some spikes and dips to make it highly variable). Describe your results. (You do not have to turn in any graphs for this question.)

4. What conditions might lead to the extinction of all light moths in this population? Refer to at least one non-adaptive evolutionary mechanism in your answer to this question.