

# NATURAL SELECTION IN PEPPERED MOTH POPULATIONS

## LAB POP 1.COMP

Adapted from "Assignment #3: *Simulation of Natural Selection in Peppered Moth Populations*" Dr. Ann Throckmorton, Population Ecology, Westminster College.

Moth Simulation Website: <http://cas.bellarmine.edu/tietjen/>

## INTRODUCTION

### THE THEORY OF NATURAL SELECTION

In 1831, Charles Darwin began a five-year journey as ship's naturalist on the H.M.S. Beagle. During this time, he visited South America, Australia, South Africa, and islands of the Pacific (Galapagos Islands) and South Atlantic. It was on this voyage that he made the observations set forth in his book, *The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life* (published in 1859 and more commonly known as "*The Origin of Species*"). Darwin's contribution was to provide a mechanism through which evolution could function. Briefly, the Darwinian argument is as follows:

1. ***Variation exists within a species.*** Although we may consider all houseflies as being more-or-less alike, on closer examination you find that they are nearly as recognizable as one person is from another.
2. ***Some of this variation has a genetic basis.*** Evolution can act only on traits that are passed genetically from one generation to the next. Evolution cannot work on non-genetic differences caused by trauma, parasitism, and other environmental variation.
3. ***The reproductive potential of organisms is vast.*** Darwin calculated that a single pair of elephants could have 19 million descendants within 750 years if each animal lived to be 100 and each pair had six calves. Calculations for other organisms produce similar increases in population size. Elephants are not the most common beasts, the oceans are not overflowing with fish, and we aren't nose-deep in ragweed (although it sometimes seems that way). Therefore, something must happen to all these extra offspring and most of the young must die before they reproduce.
4. ***Because individuals differ from one another, some should be more capable than others in eluding predators, coping with environmental extremes, or in competing with members of their own or other species. Those that are more capable should leave more offspring to the succeeding generation.*** Since some aspects of coping must be tied to genetic attributes, the favorable genes are passed on to the next generation. In this way, the genetic makeup of the population changes and

evolution is said to occur. This varying reproductive success of individuals based on their different genetic constitutions is natural selection.

Often the concept of natural selection is simplified to "survival of the fittest". Fitness in evolutionary terms has an exact meaning related to the number of surviving offspring produced by an individual in comparison to other individuals in the population. Evolutionary fitness is therefore more than just the ability to run quickly or fight off competitors.

Evolution is not a historical process; it is occurring at this moment. Populations constantly adapt in response to changes in their environment and thereby accumulate changes in the genes in its gene pool. In this exercise, you will explore some of the evidence for evolution and will examine a few of the mechanisms through which evolution acts.

### PEPPERED MOTHS

The response of the peppered moth (*Biston betularia*) to industrial pollution in England is a well-known example of selection in natural populations. In brief, the peppered moth is found in two forms (or "morphs"): a mottled (light) form and a dark-colored melanic morph. A single gene controls the expression of this trait, with the melanic form of the gene dominant over the light form of the gene. During the mid 1800s, mottled moths dominated the English countryside. By 1898, however, the situation was reversed and the melanic (dark) form made up the greater percentage of the population.

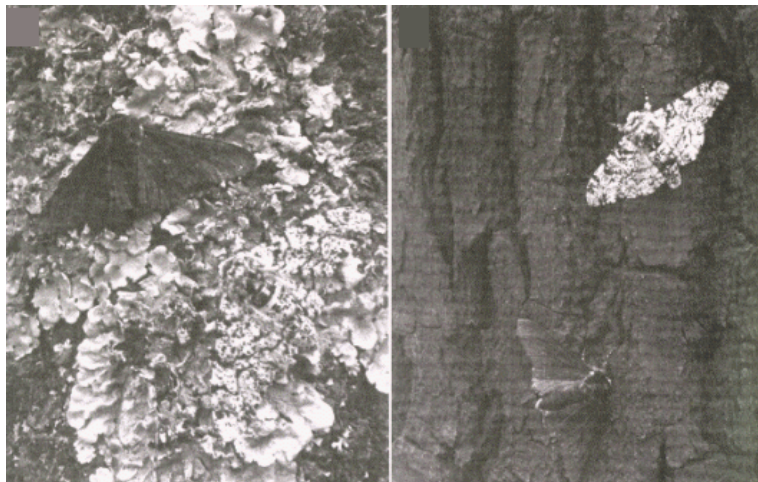


Figure 1 Comparison of camouflage of the mottled and melanic moths.

Researchers noted that the spread of the melanic form paralleled an increase in industrial pollution. They hypothesized that the melanic form was better camouflaged than lighter morphs when they settled on soot-darkened tree trunks (Figure 1). These observations

suggested that the light forms were removed from the population by birds because they were so conspicuous. Additional support for this idea came from non-industrial regions (and areas upwind from polluters) where the mottled form greatly outnumbered the melanic moths. Here the selection was reversed and the mottled moths had the advantage in hiding from birds on the lichen-covered trunks.

The hypothesis was tested by releasing an equal number of melanic and mottled forms in an unpolluted area and then observing birds feeding. Birds had difficulty recognizing the mottled moths against the lichen background and ate relatively few of them. In another series of experiments, it was found that the melanic form had the advantage in polluted areas.

Recaptured from unpolluted areas	Recaptured from polluted areas
14.6% of light moths	13.0% of light moths
4.7% of dark moths	27.5% of dark moths

Recent advances in controlling pollution have returned many areas of Great Britain to their previous state. With this, the peppered moth population is shifting again toward the mottled form.

In reality, the Peppered Moth story is not as cut-and-dry as it may seem. Recent research has shown that the moths don't normally spend much time sitting on trees in the wild, suggesting that selection by birds based on camouflage is more complicated than we originally anticipated. Nonetheless, something is happening that is related to selection. As you complete this assignment, keep in mind that the whole story is not yet known.

## **PURPOSE**

The purpose of this activity is to study the effect of natural selection on a simulated peppered moth population and to examine a few of the mechanisms through which evolution acts.

## **EQUIPMENT/MATERIALS**

Laptop computer with "Moth Simulation" program downloaded to desktop.

## **PROCEDURE**

1. The software for this simulation is loaded on the Dell laptop computers. Press the power button to turn on the computer. A Novell Client Login window will appear. Click in the box marked "Workstation only". The word "sim" should appear in the Username window (if it doesn't, type "sim" in the window manually). The password is "sim" (all lowercase letters). Once the desktop is loaded, there is an

icon on the desktop labeled “Shortcut to Moth.EXE”. Double-click the icon to start the simulation.

2. You can select the level of pollution in the environment – low, medium, high – by pressing one of the buttons at the upper right corner of the window. Select "Low." Note that the tree bark background changes to an unpolluted state.
3. Towards the bottom of the window, look for a box titled “Before Selection.” Here, you can enter how many moths of each color you want to start with. Start with 25 of each color.
4. When you're ready to run the simulation, press the "Do It!" button. Dark (melanic) and light (peppered) moths are randomly scattered over the tree bark background. Melanic forms are represented by the dark spots, the light moths by the light dots. “Feed” on the moths as quickly as possible (you only have 10 seconds) by moving the cursor over your prey and clicking on it. (The assumption is that you will eat the moths that are the easiest to see.) If you have successfully fed, the prey will turn red.
5. After your 10 seconds has expired, the mouse reverts to the normal pointer and you can no longer feed. After the first “feeding”, the yellow data sheet will show two sets of data, the parental (row 1) allelic frequency and the post-feeding allelic frequency (row 2). The frequency of the dark gene is in the left-hand column, the light gene frequency is in the right-hand column. Have one member of your lab group record these allelic frequencies in the chart provided on the Data Sheet.
6. Erase the "Finished" message box by clicking on it and click on “Next Generation” to generate the number of moths in the next generation based on the current gene frequencies. The program figures out the proportions for the next generation by using the Hardy-Weinberg equilibrium formula ( $p^2 + 2pq + q^2 = 1.0$ ). It then uses these frequencies to figure out how many light-colored (mm) and dark-colored (MM or Mm) moths will make up the new population.
7. Press the "Do-it!" button when you're ready to start feeding. Feed as above. Again, after feeding a new allelic frequency will appear in the yellow data sheet for both the dark and light genes. Record these in the data sheet provided with the lab.
8. Continue until one or the other genes have been eliminated from the population or until you've completed 15 generations. There is a small box labeled “Generations”

just below the yellow data sheet. This will keep track of how many generations you have completed.

9. Re-run the simulation for the medium and high-pollution environments by following Steps 3-8. Do not forget to reset the moth population at 25 for each type of moth when you start a new pollution level. Add the allele frequency data to your medium and high pollution data sheets.

**DATA SHEET**

Name \_\_\_\_\_

Name \_\_\_\_\_

Period \_\_\_\_\_ Class \_\_\_\_\_

Date \_\_\_\_\_

**NATURAL SELECTION IN PEPPERED MOTH POPULATIONS**

**DATA TABLES**

**LOW POLLUTION**

<b>Generation #</b>	<b>Frequency of Dark Gene</b>	<b>Frequency of Light Gene</b>
Parental		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

**MEDIUM POLLUTION**

<b>Generation #</b>	<b>Frequency of Dark Gene</b>	<b>Frequency of Light Gene</b>
Parental		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

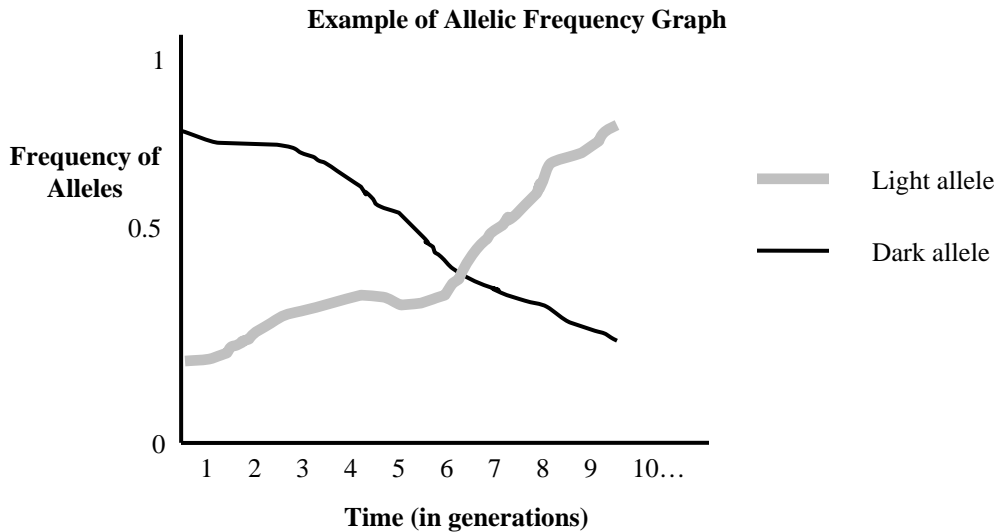
**HEAVY POLLUTION**

<b>Generation #</b>	<b>Frequency of Dark Gene</b>	<b>Frequency of Light Gene</b>
Parental		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

## ANALYSIS

Make a line graph (as shown in the example below) for **each pollution level** that shows how the frequency of the dark and light allele changed with time. (x-axis = time in generations, y-axis = frequency of alleles, two lines – one for the dark allele, one for the light allele).

**NOTE:** Refer to your graphs to answer Questions 1 and 2.



## QUESTIONS

1. What happens to the natural selection process under extreme conditions (e.g., no pollution or heavy pollution)? What happens to the dark and light genes and in what time frame (in generations)?



2. What happens to the natural selection process under intermediate conditions (medium pollution)? Under these conditions, what happens to the dark and light genes and in what time frame (in generations)?
  
3. How does the change in allelic frequency demonstrate natural selection at each pollution level?
  
4. In what way(s) does this simulation differ from what happens to predators and prey in a real setting? What could be done to make this simulation more realistic?

**Extra Credit:** This computer simulation is an example of *camouflage*, just one of many prey avoidance mechanisms. Think of two other distinct types of prey avoidance mechanisms.

