

The Peppered Moth Simulation Activity (Wet Lab)

Teacher Prep Notes

Lesson Objectives:

1. To illustrate the principles of natural selection and variation within a species
2. To illustrate how natural selection can produce shifts of phenotypic frequency within a population

Ministry Expectations:

Overall Expectations:

C2 Investigate evolutionary processes, and analyse scientific evidence that supports the theory of evolution
C3 demonstrate an understanding of the theory of evolution, the evidence that supports it, and some of the mechanism by which it occurs

Specific Expectations:

C2.4 Investigate, through a case study or computer simulation, the process of natural selection and artificial selection, and analyse the different mechanisms by which they occur

C3.1 Explain the fundamental theory of evolution, using the evolutionary mechanism of natural selection to illustrate the process of biological change over time

C3.2 Explain the process of adaptation of individual organisms to their environment

Student Learning Goals:

After this activity, students should be able to:

- Demonstrate the importance of variation within a species
- Relate how environmental changes can affect the survival of a species
- Explain how natural selection can cause populations to change

Prior Knowledge:

Before performing this activity, students should already have the understanding of:

- Basic understanding (introductory knowledge) of natural selection
- Adaptation
- Characteristic variation within a species

Assessment Strategies:

Students will hand in their laboratory worksheet the following day after this experiment. This assignment will be an Assessment for Learning (AFL), which will not count towards marks but be a diagnostic to ensure students understand the concept of natural selection.

Materials needed:

- Hole punch (1)
- Cups (1 per each group)
- Sponges (1 per each group)
- Hunter's tool (finger)
- Print-out of backgrounds (1 per group) & for moths punch outs [*end of this word document for templates*]
- Pieces of paper to cover the activity prior to starting it (1 per group)

Teacher's Notes:

Time required: 1 - 75 minute class period + prep time

This activity is not intended to recreate the peppered moth example, but rather uses the example of the peppered moth to illustrate the basic principles of genetic variation within the species of the peppered moths in regards of colour: light gray, medium gray (intermediate colour), and dark gray.

The purpose of this activity, the various coloured sheets of paper will represent a changing environment. The paper dots, created with the hole punch, will represent the moths (prey) and the students represent the birds (predators to the moth). To save time, pre-hole punch all moths and packaged prior to the lab.

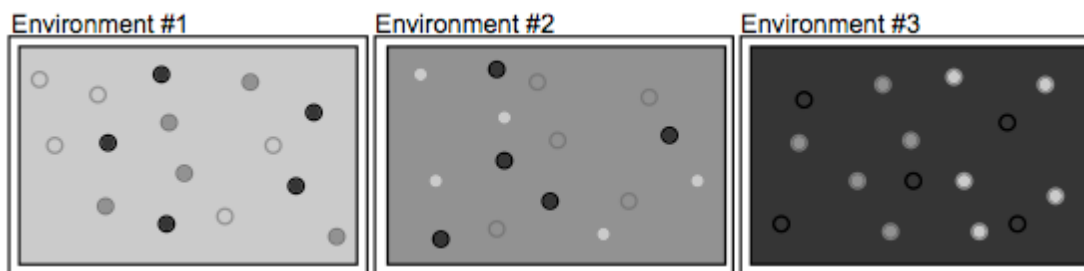
Each environment will contain 90 moths (30 of each phenotype). The birds should be focused on eating quickly. This is a timed exercise, you should communicate to the students that speed is the objective to "eat" as much as moths.

Additional Tips:

1. Do not allow students to observe or study the environments (sheets of paper with various coloured dots) prior to hunting. I recommend concealing each environment by placing a second sheet of paper over each one before the students are allowed to start hunting. The average student, focused on performing the action quickly, may not even notice the color variations.
2. This activity can be done as a class-group activity in which the whole class participates in the hunting and data collection.
3. If students have already learned the genetics unit prior to evolution, you may integrate allele frequency into this activity, in which the light gray is homozygous recessive, medium gray is heterozygous, and dark gray is homozygous dominant and investigate how the allele frequency shifts due to natural selection.
4. Misconceptions may arise due to this activity, ensure to discuss with the students to prevent them
 - a. More than one adaptation infers the survival of individuals in a population
 - b. Predators also have adaptations to infer their own survival to eat their prey
 - c. Reproduction is not as simple as stated in this example depends on type of reproduction, ratio of male to female, and survival of the offspring, etc.

Instructions:

1. Split up your class into groups into 4-5 (depending on how many areas you have set up).
2. Set up designated areas for each group, similar to the figure below. Each environment should contain 90 moths, 30 of each phenotype and COVER all the environments before the students are in the class.



3. Rotate roles, one student should be a time-keeper to ensure that each student has 30 seconds to hunt and a hunter. Everyone should hunt once in each round of hunting.
4. One student at a time to hunts. Student will have to moisten their index finger on a wet sponge. The objective of the hunter is to capture one moth from each of the three environments and drop it into the designated cup for group (the dots will stick to their moist fingertip). Give the student 30 seconds to feed (can adjust the number depending on your class size)

- Repeat until the whole group has done one round of hunting.
- Now, have the group should count the number of different types of moths that survived in the environments of 1, 2, and 3. Have the students fill in their table below. You may have to provide some assistance. Do not allow students to continue on after Table 1 is completed.

Table #1: First Generation:

Peppered Moth Population (Natural Colour Variation)	Environment					
	#1: Manchester (before 1845)		#2: Manchester (25 yrs after 1845)		#3: Manchester (50 yrs after 1845)	
	Number of Survivors	Percentage (%) of Survivors	Number of Survivors	Percentage (%) of Survivors	Number of Survivors	Percentage (%) of Survivors
Light Gray						
Medium Gray						
Dark Gray						
Total Number of Moths in Environment						

Reminder: Each environment started with 30 moths of each colour. Therefore, the number of survivors should be = 30 - number eaten

- Once you've done a check of Table#1 within all groups. Communicate with your students that the eaten moths are now dead and will not contribute to habitat and should not be placed back into the habitat. Now, after calculating the number of survivors, it's now time to determine the next generation of moths. Assume that reproduction occurs and that each type of moth in each habitat will be now TWICE the number of surviving moths of that appropriate colour and habitat. Have the student record that information in a chart that should look like the one below: Some student may require scaffolding; it may be beneficial to write the formula on the board.

Table #2: Second Generation Population:

Peppered Moth Population (Natural Colour Variation)	Environment		
	#1: Manchester (before 1845) Population of Generation #2	#2: Manchester (25 yrs after 1845) Population of Generation #2	#3: Manchester (50 yrs after 1845) Population of Generation #2
Light Gray Moths	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =
Medium Gray Moths	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =
Dark Gray Moths	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =	# remaining + 2 (# remaining) =
Total Number of Moths in Environment			

Note: Please note the STARTING population of the second generation for Table #3.

8. Now, repeat the hunting as in step 1-4 and use a new table to record the survival of the second generation.

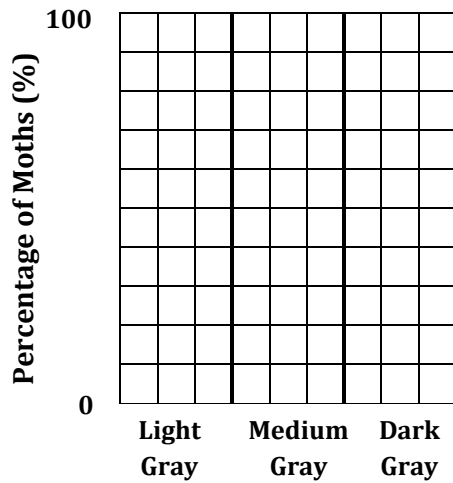
Table #3: Second Generation:

Peppered Moth Population (Natural Colour Variation)	Environment					
	#1: Manchester (before 1845)		#2: Manchester (25 yrs after 1845)		#3: Manchester (50 yrs after 1845)	
	Number of Survivors	Percentage (%) of Survivors	Number of Survivors	Percentage (%) of Survivors	Number of Survivors	Percentage (%) of Survivors
Light Gray Moths						
Medium Gray Moths						
Dark Gray Moths						
Total Number of Moths in Environment						

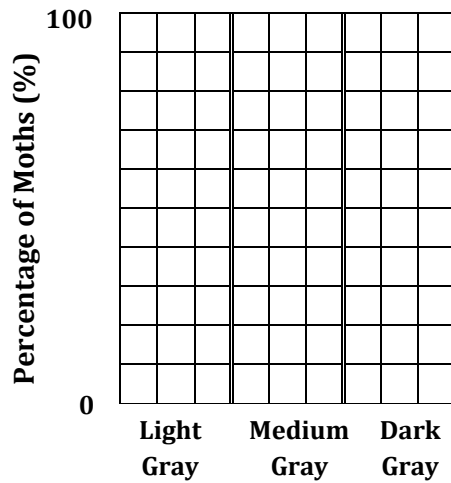
Note: # survivors = starting population from Table #2 - # eaten

9. Students should use the data from *table 1* and *table 2* to complete the following two (2) bar graphs for each environment. Some students may need extra help if they are unfamiliar with bar graphs.

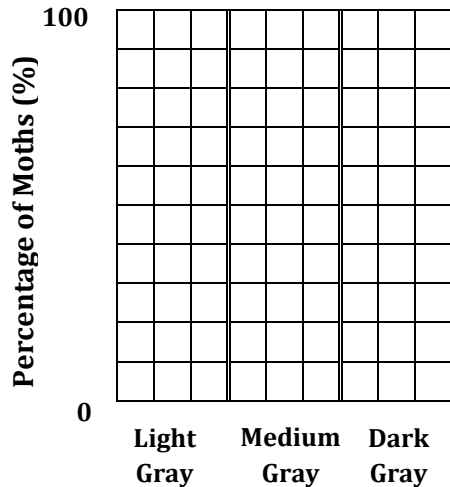
First Generation Moths in Environment #1



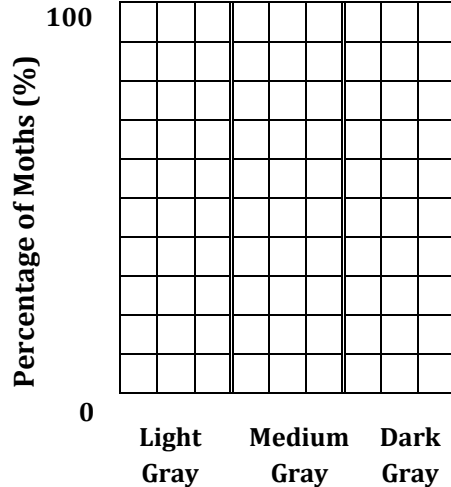
Second Generation Moths in Environment #1

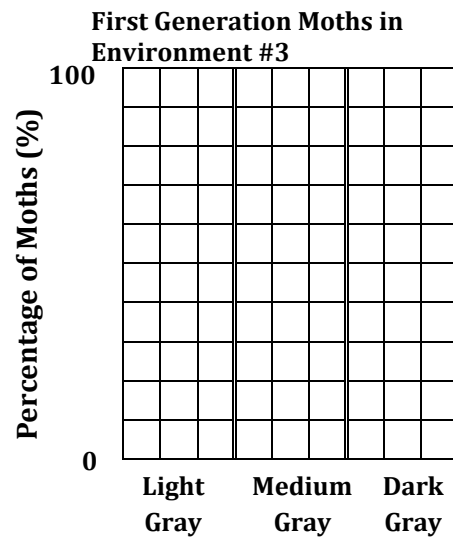
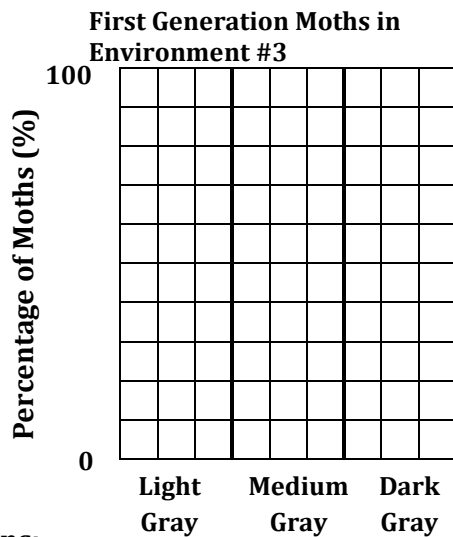


First Generation Moths in Environment #2



Second Generation Moths in Environment #2





Questions:

1. Define variation.

Variations are structural, functional, or physiological differences between individuals.

2. Define adaptation.

An adaptation is a structure, behaviour, or physical process that helps an organism survive and reproduce in a particular environment. (Ex. Camouflage)

3. What adaptation did certain moths have that increased their survival?

Camouflage

4. What color were the majority of the peppered moths before 1845?

Light coloured (peppered)

5. What caused the first dark gray moths to appear within the population?

A mutation, which the soot production (pollution) due to the industrialization of Manchester caused lichens to die, which allowed the dark gray moths to have an advantageous adaptation.

Questions 6-7, use only the Bar graphs for the **first** generation to answer the questions.

6. Which moths seem to have the *greatest* and *lowest* fitness for environment #1? Why?

Greatest = Light gray coloured moths; lowest = dark gray moths; due to camouflage to the background.

7. Which moths seem to have the *greatest* and *lowest* fitness for environment #2? Why?

Greatest = Medium gray coloured moths; lowest = light or dark gray moths; due to camouflage to the background.

8. Which moths seem to have the *greatest* and *lowest* fitness for environment #3? Why?

Greatest = Dark gray coloured moths; lowest = light gray moths; due to camouflage to the background.

9. Compare the bar graphs from the **first** generation and **second** generation for each environment and describe any trends or patterns.

Students should notice a directional shift towards the coloured trait that best blends in (camouflages) to the environment. After several generations, the dark gray should be selected for and the overall population will be mainly made up of dark moths.

10. Explain how environmental changes can impact the survival of a species due to their characteristics.

Since an adaptation helps an organism survive in a particular environment, when that environment changes that adaptation may not be suitable anymore for this new environment. Thus another adaptation within that species may allow better survival than the other.

11. Explain why the light forms of the peppered moths are still common in the country regions?

Less pollution, therefore, the light form can still effectively camouflage itself and survive.

12. From your textbook, England enacted clean-air legislation in the 1950s, and lichen began to grow on trees again. Predict the ratio of the coloured moth population you expect to see in Manchester and explain your reasoning.

*Expect that dark gray-black peppered moths will be rare again since lichens will allow camouflage for the light moth to have better survival and reproduce offspring.
(It is estimated that by 2019 the black peppered moth will again be as rare in Manchester as it was before the Industrial Revolution Source: McGraw Hill Biology 11 2010)*

13. Now, thinking outside of this example, is appearance the only characteristic that determines whether an individual plant or animal is suited to its environment? If so, explain. If not, please give an example of another characteristic(s) (adaptation) that could increase an organism's chances of survival.

Appearance is not the only characteristic that determines whether or not an individual is suited to its environment. [Many answers are acceptable: some examples are auditory mimicry, speed/agility, foul smelling, toxins (bad tasting), wings, eye-sight, etc.]

14. In your opinion, is natural variation within a population beneficial to the long-term survival of a population (or species) as a whole? Please explain, why or why not.

Variation within a population is essential for the long-term survival of a population as a whole because the environment always changes, and a trait that may be well adapted for one environmental condition may not be well suited for another, thus if more adaptations exist within that population, that population can continue to exist and those adaptations that are well suited will become more common in the population. If there were not variation, the population or species will be at risk for extinction if the environment changes.

15. "Survival of the fittest" is a common expression. What do you think most people mean by this expression? How would you explain this expression to help someone understand how natural selection actually functions?

Survival of the fittest means that an organism has favourable combinations of features that allows it to have better survival to reproduce than others. The organism is well adapted to the environment and these features (heritable traits) will be passed on to their offspring and gradually these features will become more common in the population, and less desirable features will disappear which is Natural Selection.

References:

Simulation adapted from:

- Jason Orbaugh - "The Peppered Moth Simulation Activity"
- Drs. Jennifer Doherty & Ingrid Waldron, Department of Biology, University of Pennsylvania "Evolution by Natural Selection"

Images from:

- <http://en.wikipedia.org/wiki/File:Biston.betularia.7200.jpg> (accessed: 26/01/2011)
- <http://en.wikipedia.org/wiki/File:Biston.betularia.f.carbonaria.7209.jpg> (accessed: 26/01/2011)

Environment #1



Environment #2



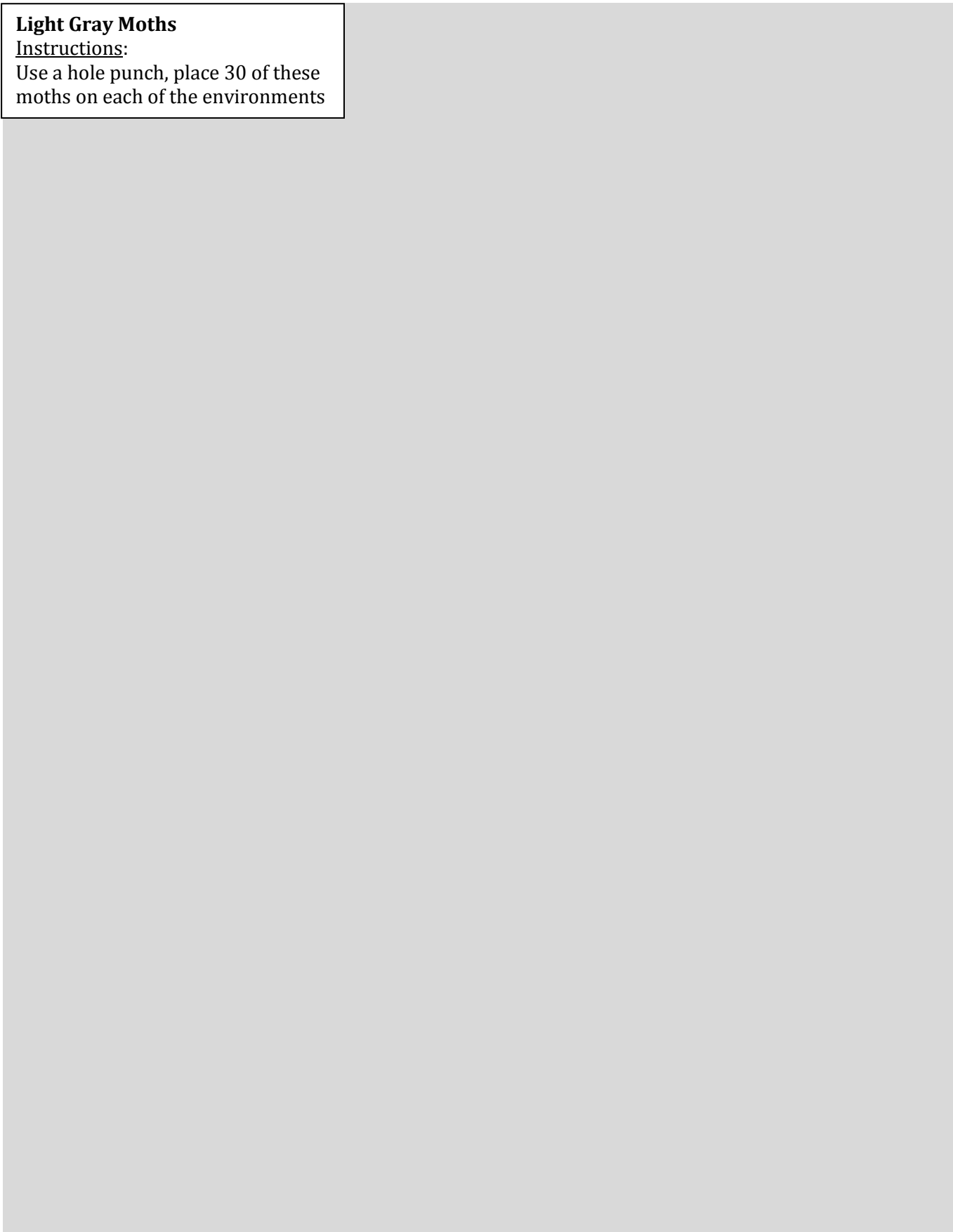
Environment #3



Light Gray Moths

Instructions:

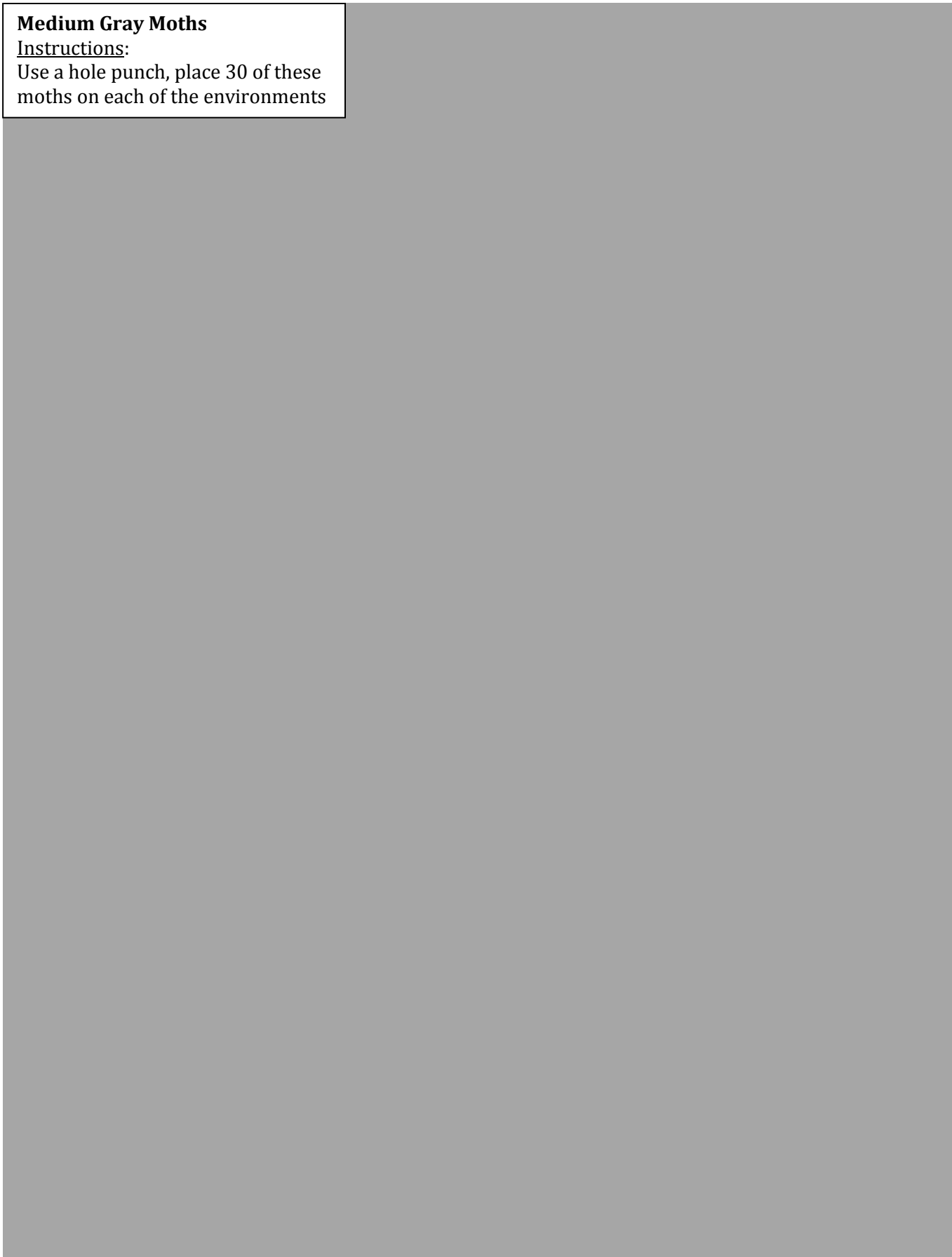
Use a hole punch, place 30 of these moths on each of the environments



Medium Gray Moths

Instructions:

Use a hole punch, place 30 of these moths on each of the environments



Dark Gray Moths

Instructions:

Use a hole punch, place 30 of these moths on each of the environments

