What the Moths Taught Us

The Story Begins: **Kettlewell's Problem**

Henry Bernard Davis Kettlewell was a biologist in Oxford University. He was interested in studying peppered (spotted) moths**.** These moths had two types of wing coloration – light and dark.

Figure 1: Light-winged (on the left) and dark-winged (on the right) peppered moths (images taken from creative commons)

Until the year 1848, the number of light-winged moths was very large, forming 99% of the total moth population in the forest. However, over the course of the next 100 years, the population of the light-winged moths reduced to a mere 5% of the total moth population, whereas the dark-winged moths now represented 95% of the moth population. Dark-winged moths tended to outnumber the light-winged ones particularly near the industrial cities. This phenomenon was called **industrial melanism**. In the term "industrial melanism", melanism originates from the word melanin. Melanin is the pigment responsible for human skin colour, and an increase in melanin leads to darker colour. Since the dark-winged moths had increased in proportion near industrial cities, the term "industrial melanism" was used to describe the change. Kettlewell wanted to understand why the proportion of dark-winged moths near industrial cities had changed in this way.

Kettlewell knew that peppered moths were prey to many insect-eating birds. It was also known that the moths rested on tree-trunks with their wings open. Kettlewell thought of a possibility that the wings could camouflage (i.e., be hidden from sight due to similarity) with the background and would provide the moth some protection against predatory birds.

Thus, when the tree bark and lichen growing on them was light-coloured, moths with light-colored wings were camouflaged, but those with dark wings were more likely to be visible to predators. When industrialised areas in Britain became heavily polluted due to coal burning, smoke from the burning coal killed lichens and caused the trees to darken with soot. According to Kettlewell, the light-coloured moths became noticeable against a dark background and thus became an easier prey for birds.

Questions:

1. What are the similarities between the game you played and the problem that Kettlewell was dealing with?

2. Each group of students is likely to have started with a different number of dark and light chits. At the end of the game, both dark and light chits would have decreased.

   a. Calculate the decrease in the number of **dark** chits between the first and the last day. Which group of students saw the greatest decrease?

   b. Calculate the decrease in the number of **light** chits between the first and the last day. Which group of students saw the greatest decrease?

   c. Calculate the percentage decrease in **dark** chits between the first and the last day. Which group of students saw the greatest decrease

   d. Calculate the percentage decrease in the **light** chits between the first and the last day. Which group of students saw the greatest decrease?

   e. Is it better to compare between the groups using whole numbers or percentages? Why?

3. Let us look at how the number of dark and light chits changed with the passage of time.

    a. Draw a graph showing the number of dark and light chits on each "day".

        i. Which variable do you think should go on the x-axis of your graph?

        ii. Which variable should go on the y-axis of your graph?

    b. Using your graphs, predict what will happen to the number of dark chits and the light chits, if the game is played further.

    c. You predicted what would happen to the number of dark and light chits if the game is played further. Do you think the same thing would have happened to the moths in Britain studied by Kettlewell?

4. Let's think about how the color of the moths changed.

    a. Think of each moth separately. Did the color of the individual moths change?

    b. Now, think of the moths together, as a group. Did the color of the group of moths change?

    c. If your answer to question (b) was "yes", then why or how do you think the change occurred?

    d. Based on the game, do you think the color of individuals needs to change in order for the color of a group to change? Why?

The story continues….
Kettlewell thought that there might be fewer light-winged moths near industrial areas, because light-winged moths would be more easily visible to predator birds. But he needed to test this guess using an experiment. To do so, he **marked** the underside of the wings of some moths and **released** them at sundown in a polluted forest near the city of Birmingham in England. In the following week, every evening, the marked moths were **recaptured** using various traps. Such an experiment is called a mark-release-recapture experiment. The following table represents the number of moths recaptured:

	Polluted Forest (Birmingham)
Light Wings	18/137
Dark Wings	136/493

The numbers in the table indicate the number of moths recaptured out of the number of moths marked and released. For example, 18/137 indicates that out of 137 moths marked and released, 18 were recaptured.

Questions:

1. Let's play with some numbers:
    a. What percentage of light-winged moths were recaptured?

    b. What percentage of dark-winged moths were recaptured?

    c. Which type of moth was more likely to be recaptured – light-winged or dark-winged?

    d. Look at the percentages that you calculated in your game. Were they similar to those found by Kettlewell?

2. What do you think happened to the moths that were not recaptured?

3. Kettlewell's fellow biologists were not convinced by some parts of what he was saying about the moths. They agreed with some of Kettlewell's points, but disagreed with some other points. The reasoning by these two groups are represented by empty boxes in Other Biologists' column shown below:

Kettlewell	Other Biologists
There are moths on the trees	There are moths on the trees
↓	↓
Birds prey on the moths	Birds prey on the moths
↓	↓
Birds are able to see white moths more clearly	
↓	↓
Birds prey more on the moths which they see clearly	
↓	↓
Fewer white moths survive	Fewer white moths survive

The other biologists thought there could be other reasons why fewer white moths survived. What line of reasoning can you think of that leads to the same result – survival of fewer white moths?

4. What experiments could Kettlewell have conducted to convince his biologist colleagues that he was right?

References:

1. "H.B.D. Kettlewell & the Peppered moths" by Joel B. Hagen, in Doing Biology, publisher: Benjamin Cummings.

2. "Industrial Melanism in the Peppered Moth, Biston betularia: An Excellent Teaching Example of Darwinian Evolution in Action" by Michael E. N. Majerus, in Evolution: Education and Outreach, 2 (2009) pp. 63 – 74.

Appendix 1

Enter your data from the moths and birds game here.

	Number of chits on the board			**Percent Remaining**	
	Dark (D)	**Light (L)**	**Total**	**Dark (D)**	**Light (L)**
Start					
After Day 1					
After Day 2					
After Day 3					
After Day 4					
After Day 5					
After Day 6					
After Day 7					

