**Lesson #6**

# Microbe Power - Using a Winogradsky Column as a Battery

**Objectives:**

- The learner will demonstrate analysis of the changes taking place in the bottle by measuring and graphing changes in voltage and current.
- The learner will demonstrate application of the interactions happening in the bottle by applying these changes to the environment.

**National Science Education Standards:**
**UCP 2, UCP 4, SAI 1, SAI 2, PS 3, LS 3, HNS 2**

**Benchmarks:**
**1C, 2B, 4B, 4D, 4E, 5E, 8C, 9D, 11A, 12B, 12D**

**Materials:**

DC Voltmeter measuring in millivolts
DC Ammeter measuring in microamps
Alligator clips with lead wires
Winogradsky column (see Lesson #5)

**Background:**

Just as the microbes in the Winogradsky column are changing their environment in ways that we can see, they are also making changes which are not so easily noticed. As the iron in the bottle is being used by the bacteria, there are processes at work changing the iron itself. $Fe^{2+}$ is being oxidized to form $Fe^{3+}$, and $Fe^{3+}$ is being reduced to form $Fe^{2+}$. In the simplest of terms, the difference between these two ions is a difference of electrons. As $Fe^{2+}$ is being oxidized to form $Fe^{3+}$, an electron is lost from that atom of iron. It is the bacteria in the bottle which are helping this to happen. Some of the bacteria remove electrons from iron and transfer them to oxygen (an electron acceptor). Others act take the electrons from the food that was added and transfer them to the iron (an electron donor). This causes an imbalance in the number of free electrons at different heights in the bottle.

Because we can not see these changes we must find another way to measure the changes taking place within the bottle. One way that we can measure the changes is by using a voltage meter and an ammeter. The voltage meter allows us to quantitatively measure the difference in the number of free electrons at the top of the bottle as compared to the bottom of the bottle (the electric potential). The ammeter measures the current flowing through the bottle. While working on this activity, remember the steps of the iron cycle and the conditions which are necessary for bacteria to interact with the iron.

**Preparation:**

This activity requires little teacher preparation. The Winogradsky bottles from a previous activity will be used. Be sure to spend some time experimenting on your own with the voltmeter to be sure it is on the proper setting to register millivolts. It is advisable to do the same with the ammeter.

**Warm-Up:**

How do batteries work? Briefly discuss the parts of the battery and how they work.

**Procedures:**

1. Connect the positive wire of the voltmeter to the top electrode.
2. Connect the negative wire of the voltmeter to the bottom electrode.
3. Record the voltage shown on the meter.
4. Repeat procedures 1-3 daily for the next three weeks. Record the voltage each day in the data table below.
5. Repeat steps 1-4 for the ammeter.

The procedures for this lab are relatively simple and should only take a few minutes to complete each day once the initial lesson has taken place. You may want to have a station set up so that students may find their voltage readings at the beginning of class each day.

The graphing portion of this activity will not take place until after all of the data has been collected. See below for various methods of completing this portion of the activity.

**Variations and Follow-Up Activities:**

The procedures for the graphing portion of the activity will depend on the levels of your students and their access to computers. The data may be graphed by hand or using a computer program. There are many good graphing programs available for students to use. One of the more common programs used by students is Excel™. If your students have access to Excel™ and know how to use it, this may be the way to graph the data. For students who are not as familiar with Excel™, this could be completed together as a class or you could type directions for students to follow. Again, depending on the version of Excel™ and the platform being used, these directions will vary. An example of a graphing activity is given in Lesson #8.

If you do not have access to a computer graphing program, graphing by hand is a realistic option. Be sure to review proper procedures with students before beginning. It may be helpful to spend some time talking about the scale the students will need to use in setting up the graph so that it fits the paper. Even if you will have your students graph the data using a computer, it can still be a worth-while experience to have them graph by hand as well. This would provide for an excellent comparison of the computer graph versus the hand made graph. Students may notice some differences in the graphs. It is important for students to realize that even though they are putting the same information into the computer, it sometimes sets up the graph differently.

**Assessments:**

Informal assessments can be made throughout the lab activity through observations of student work. The analysis and conclusion questions are designed to assess students' knowledge of the activity as well as their ability to extend their knowledge beyond the classroom. The graphing portion can be an important tool in assessing students' analysis skills.

**Observations:**

This lesson, which will be revisited over many days, starts out slow. I had my students make connections between the changes in voltage and the changes in the appearance of the bottle. This was also an easy lesson for students to take measurements and collect data on their own. Encourage students to record current and voltage daily while being careful not to break the electrodes.

I found that my students had a hard time understanding the amount of voltage coming from the bottle. Showing them a AA battery hooked up to the voltmeter helped them to better understand the amount of energy the bottle was producing. The AA battery is a 1.5 volt battery.

A brief review of electricity may be helpful for students. The diagram "Electrical Potential Generated by the Iron Cycle" in this lesson is a great way to review this. Remember, some of the information presented in the background is for your understanding and can help you to answer student questions. My students never read any of the teacher background information for this lesson and I did not discuss any of it with them, but they were still able to successfully complete the activities in the lesson.

The graphing portion of the lesson is a great exercise in analyzing and interpreting data. My students and I talked about the need to make our own decisions about how the data was to be presented and used. It is important for students to understand that they need to think about making their own decisions as opposed to having the computer make decisions for them. When students see the graph they create, their first question to themselves should be, "Does that make sense?"

Name ____________________
Date ____________________
Microbe Power

**Problem:** Some of the changes occurring in the bottle are easy to see while others can not be seen at all. How can these changes be measured? Specifically, how can the changes in the states of the iron be measured?

**Background:**

Just as the microbes in the Winogradsky column are changing their environment in ways that we can see, they are also making changes which are not so easily noticed. As the iron in the bottle is being used by the bacteria, there are processes at work changing the iron itself. $Fe^{2+}$ is being oxidized to form $Fe^{3+}$, and $Fe^{3+}$ is being reduced to form $Fe^{2+}$. In the simplest of terms, the difference between these two ions is a difference of electrons. As $Fe^{2+}$ is being oxidized to form $Fe^{3+}$, an electron is lost from that atom of iron. This causes an imbalance in the number of free electrons at different heights in the bottle.

Because we can not see these changes we must find another way to measure them. One way that we can measure the changes is by using a voltage meter and an ammeter. The voltage meter allows us to measure the difference in the number of free electrons at the top of the bottle as compared to the bottom of the bottle (the electric potential). The ammeter measures the current flowing through the bottle. While working on this activity, remember the steps of the iron cycle and the conditions which are necessary for bacteria to interact with the iron.

**Hypothesis:** If ________________________________________________,

then ________________________________________________________,

because ______________________________________________________

______________________________________________________________

**Materials:**

DC Voltmeter measuring in millivolts
DC Ammeter measuring in microamps
Alligator clips with lead wires
Winogradsky Column (see prior activity)

**Procedures:**

1. Check with your teacher for any special instructions for the voltmeter which you are using. Some need to be set to a specific setting.
2. Connect the positive wire of the voltmeter to the top electrode. If you are using red and black wires, then this will be the red wire.
3. Connect the negative wire of the voltmeter to the bottom electrode. Again, if using red and black, this will be the black wire.
4. Record the voltage shown on the meter.
5. Repeat procedures 1-4 daily for the next three weeks. Record the voltage each day in the data table below.
6. Check with your teacher for any special instructions for the ammeter which you are using. Some need to be set to a specific setting.
7. Connect the positive wire of the ammeter to the top electrode.
8. Connect the negative wire of the ammeter to the bottom electrode.
9. Record the current shown on the meter.
10. Repeat procedures 6-9 daily for the next three weeks. Record the current each day in the data table below.
11. Be sure your lab station is clean and your materials have been returned to their proper location.

**Data:**

| Day | Date | Voltage (mV) | Day | Date | Voltage (mV) |
|---|---|---|---|---|---|
| 1 | | | 12 | | |
| 2 | | | 13 | | |
| 3 | | | 14 | | |
| 4 | | | 15 | | |
| 5 | | | 16 | | |
| 6 | | | 17 | | |
| 7 | | | 18 | | |
| 8 | | | 19 | | |
| 9 | | | 20 | | |
| 10 | | | 21 | | |
| 11 | | | | | |

| Day | Date | Current (μA) | Day | Date | Current (μA) |
|---|---|---|---|---|---|
| 1 | | | 12 | | |
| 2 | | | 13 | | |
| 3 | | | 14 | | |
| 4 | | | 15 | | |
| 5 | | | 16 | | |
| 6 | | | 17 | | |
| 7 | | | 18 | | |
| 8 | | | 19 | | |
| 9 | | | 20 | | |
| 10 | | | 21 | | |
| 11 | | | | | |

Analysis:

1. What was the largest voltage recorded? ______________________________

2. What was the smallest voltage recorded? ______________________________

3. What was the range of voltage readings for the 21 day test? (show your work)

4. Using your voltage data, plot a line graph of the data. Be sure that you read the numbers carefully. Record the days of the activity on the x-axis, and the voltages on the y-axis.

5. After looking at the line graph, does the information on the graph match the information in your data table? How can you tell if your line graph is correct?

______________________________________________________________
______________________________________________________________
___________________________________________________________

6. Looking at the line graph, describe how the voltage has changed. ___________
______________________________________________________________
___________________________________________________________

7. What was the largest current recorded? _____________________________

8. What was the smallest current recorded? ____________________________

9. What was the range of current readings for the 21 day test? (show your work)

10. Using your current data, plot a line graph of the data. Be sure that you read the numbers carefully. Record the days of the activity on the x-axis, and the current on the y-axis.

11. After looking at the line graph, does the information on the graph match the information in your data table? How can you tell if your line graph is correct?
_____________________________________________________________

12. Looking at the line graph, describe how the current has changed. ___________
________________________________________________________________
______________________________________________________________

**Conclusions**

1. Did your findings support your hypothesis? Why or why not? _______________
________________________________________________________________
______________________________________________________________

2. What caused bottle to give different voltage/current readings during the experiment? Describe these changes using the graph as a reference.
________________________________________________________________
________________________________________________________________
______________________________________________________________

3. Extend your understanding of the activity in this bottle to the larger environment around you. Use the following questions to guide you in writing a two paragraph conclusion of your findings. Write your conclusion on a separate piece of paper and attach it to your lab. (Hint: you may want to include a diagram if it would help you to explain your answers)

- Is this same process happening in the environment?
- What other factors may be involved in the environment which are not present in your bottle?
- How could your findings benefit people of the future? How could these findings benefit policy makers?