Microbial Fuel Cell 2
What's the Difference?

Objective

To understand how batteries and fuel cells differ.

Skill Level: High school	**Class time:** 45 min.

Materials

Per group:

- Multiple pennies (small copper coin) – preferably from before 1982, if none are available use quarters.
- Small cylindrical plastic container
- Sandpaper
- Scissors or knife
- Zinc strip (paperclips will work)
- Copper strip (optional)
- Galvanized nail (optional)

Per class:

- Voltmeter

Next Generation Science Standards

Disciplinary Core Idea:

PS3: Energy in chemical processes

LS2: Ecosystems: Interactions, energy, and dynamics

Performance Expectations:

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

Practices	**Crosscutting Concepts**
☐ Asking questions / defining problems	☐ Patterns
☐ Developing / using models	☐ Cause and effect: Mechanism / explanation

☐ Planning / carrying out investigations	☐ Scale, proportion, and quantity
☐ Analyzing / interpreting data	☐ Systems and system models
☐ Math / computational thinking	☒ Energy / matter: Flows, cycles, conservation
☒ Constructing explanations / design solutions	☐ Structure and function
☐ Engaging in argument from evidence	☐ Stability and change
☐ Obtaining / evaluate / communicate	

Background Information

Introduction:

A **fuel cell** is an electrochemical device capable of the direct conversion of chemical energy into electrical energy. It produces electricity from an external fuel (on the anode side) from which electrons are withdrawn, and then transferred to an oxidant (on the cathode side). The circuit is closed by an ion or proton exchange connection between the fuel and oxidant chamber. Fuel cells are different from batteries in that they consume reactant, which must be constantly fed into the device, whereas, batteries store electrical energy chemically in a closed system. A battery eventually runs out because there is nothing more to oxidize. Fuel cells can operate virtually continuously as long as the necessary flows are maintained. Many combinations of fuel and oxidant are possible in a fuel cell.

This activity combined with "Bacteria Power" will help you walk your students through two major principles involved in fuel cell creation: what is a battery and where does energy come from in living organisms?

Background:

The main difference between a battery and a fuel cell is that batteries have a fixed fuel stock, which will eventually become depleted making the battery "dead". Fuel cells on the other hand can run indefinitely because fuel is constantly fed into the device. What follows are activities that will help students understand first, the basic properties of a battery. Secondly, students will explore how living organisms make energy. This is to prep the students for the creation of a microbial fuel cell (MFC), which is another activity.

Inside a battery, there are two metal plates or posts called electrodes (anode and cathode) where chemical reactions take place and produce electrons. Also inside is a solution called an electrolyte (the lemon juice), which allows positive charges to move in the solution and balances the movement of electrons. In the anode there is a chemical reaction that oxidizes the metal and releases cations and electrons. The cations flow into the electrolyte towards the cathode and the electrons flow through the wire producing electricity. The anode is commonly referred as the negative electrode and the cathode as the positive electrode. There is also a porous separator in between both electrodes to prevent a short circuit while also allowing the transport of ionic

charge carriers that are needed to close the circuit. The battery will keep producing electricity until the metal on the anode can no longer be oxidized. The Figure 1 shows the electron flow in a battery.

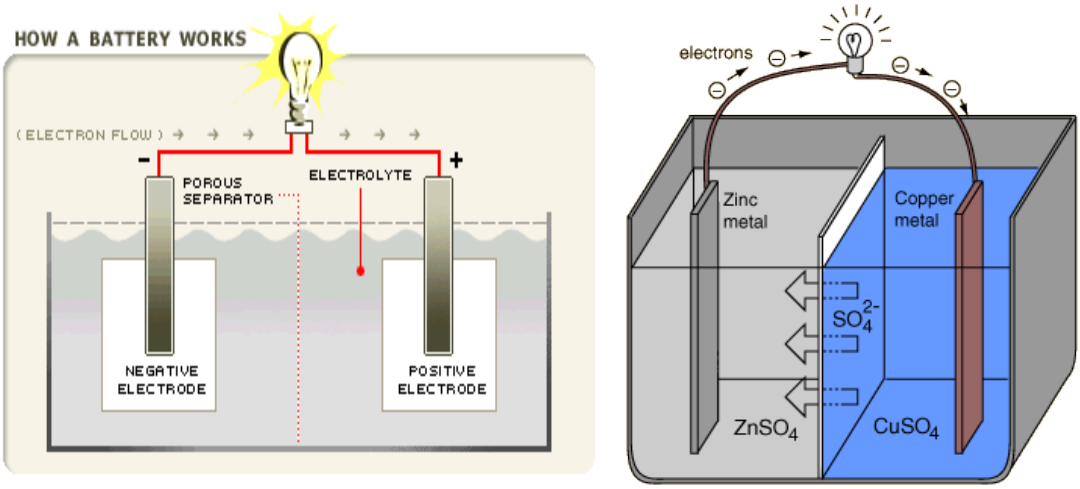

Figure 1. Electron flow in batteries

Engage

Batteries have been in existence for a very long time. Some archaeologists speculate that 3000 year-old clay pots found in Baghdad may have used for electroplating. (MythBusters recreated a version of the Baghdad Battery in their 2005 show.) The person credited with creating the first battery is Alessandro Volta. But how did he did make it? This activity builds on his elementary style to create a simple battery and help students understand the basic premise of a battery.

Explore

Experiment Questions:

- What is a battery?
- Can you make one out of household items?
- And do different materials make a difference and why?

Procedure:

1. Split students into groups of two or three.

2. Have the students take a few minutes brainstorm what they know about batteries. Have

them volunteer this information out loud.

3. Have students polish a penny (a small copper coin) with sandpaper.

4. Have students squeeze lemon juice into a bowl.

5. Have students cut out 1" strips of paper towel and fold into squares (small enough to fit into the containers). Then let these squares soak in the lemon juice until needed.

6. Have students carefully cut a slit into the bottom of the cylindrical container and pinch a penny through the slit (enough that the penny can be tested by the voltmeter while also being inside the container).

7. Set the cylinder on the table penny side down.

8. Place one square of lemon soaked paper towel on top of the penny making sure it covers the whole penny.

9. Place a zinc strip (or circularly rolled paper clip) on top of the square towel making sure that the zinc does not touch the original copper penny.

10. Measure the voltage across the cell with a voltmeter (placing one end on the penny and the other on the zinc strip).

11. Continue to add "batteries" in series to the first cell. To do this layer from bottom to top the following: 1st battery [penny–soaked towel–zinc] – 2nd battery [penny–soaked towel–zinc].....etc. (It's important to have good contact between the zinc from the 1st battery and the penny from the second battery; however the two metals within the same battery must not touch).

12. Measure the voltage across multiple batteries in series. What changed?

13. Pennies made after 1982 only have a thin layer of copper on the outside and the remaining material is zinc. Pennies from before 1982 and some from 1982 have a much higher copper content. You can hear the difference if you drop the pennies on a hard surface. If you have a real strip of copper, it will work better. Have students drop the pennies to hear the difference. Have them test and see if there is a difference? Why would they think there would be a difference? Have them test the same experiment with a copper strip to see if there is a difference in voltage.

14. Have the students replace the zinc strip with a galvanized nail. Is there a difference? If so, why?

15. Have the students try different formats of materials and make guesses as to why there would be a difference.

16. Have students share out which materials would be best to use to make a homemade

battery. Why?

Explain

The battery above is called a *wet* battery. There are many different variations that can be made. Are there other wet materials that are more conductive? Visit this ScienceBuddies.org to see a procedure about how to extend this activity. (Click links)

Current batteries used in most electronics are called dry batteries and use a paste instead of liquid. The invention of the dry battery made batteries more light and portable. As noted above, certain materials can store more energy than others. An example of this is lithium. What if the United States had an unlimited source of this conductive element? Review this article and decide how could this be helpful in our efforts to reduce our dependence on fossil fuels?

- Why does a battery stop working? What gets used up?
- Which is the cathode and anode in each battery combination? Which metal is being oxidized? Which is being reduced?
- How would the design of the fuel cell be different?

Elaborate

- Power an LED. See how to by watching this video. (Click links)
- Research the different chemicals used to make a battery. Which chemicals make the best batteries and why?
- Draw a schematic of the electron and ion flow in the lemon juice battery. Use the given schematic of a regular battery as your starting point. Make sure to label all of the parts that make up a battery (anode, cathode, electrolyte and direction of electron flow)
- This activity can be followed by the Microbial Fuel Cell activity, which creates a microbial fuel cell from dirt.

Resources

Additional Resources:

- Create a battery from a lemon. (Click links)
- How to make a battery
- What does a dry battery look like?
- Microbial Fuel Cell information and curriculum with the MFC teacher resource guide.