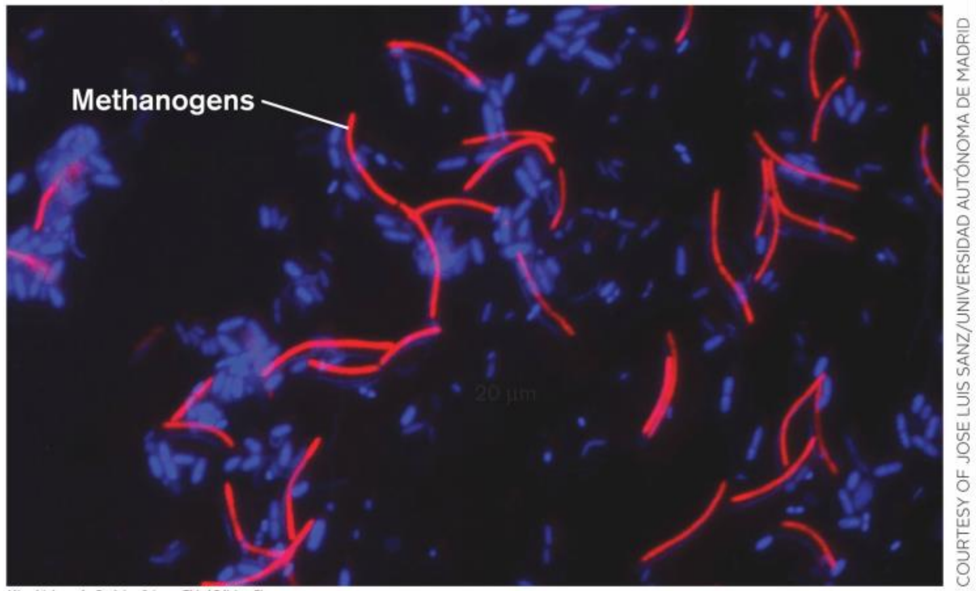
Filamentous methanogens bind bacterial communities in waste treatment



Microbiology: An Evolving Science, Third Edition Figure 19.25c

Homeschool Biology Labs: Waste Not Want Not

Name: **Date:**

"Imagine a world in which all the things we make, use, and consume provide nutrition for nature and industry—a world in which growth is good and human activity generates a delightful, restorative ecological footprint." – William McDonough and Michael Braungart

Objectives

After successfully participating in this lab, you will be able to –

- Define the term **zero waste** and understand its role in the economics of waste prevention and recycling.
- Explain the difference between **renewable** and **non-renewable** energy sources.
- Describe the difference between **biological and technical nutrients**.
- Understand the principles of **Cradle to Cradle** design.
- Describe the process of **anaerobic digestion** and production of **biogas**.

Materials

- Lab Report
- Pencil
- Plastic Bottles
- Plastic tubing
- Hot Glue
- Water
- Food waste – hot dogs
- Funnel
- Permanent Markers
- Rulers
- Graduated cylinder
- Scissors

Pre-Lab Questions

1. When you think of the word **waste**, what comes to mind? Please describe waste in your own words.

2. What types of waste do you produce at home and school?

3. Please list types of renewable and non-renewable resources in the table below:

Renewable	Non-Renewable

Background Information: Waste Not Want Not

In nature there is no garbage. Every byproduct from a natural cycle is used to fuel another. Nothing is wasted; there is zero waste. **Zero waste** is a goal of many communities and businesses that includes reducing what we consume, maximizing **upcycling**, minimizing waste, and ensuring that products are made to be reused, repaired, upcycled, or returned to nature.

In the world humans have constructed, the life cycles of things we use work a little differently. We take resources from nature to create billions of tons of things which we use once, then throw away. Each time we use raw material from the earth without replenishing it (such as cutting down a tree without planting a new tree), we are depleting a natural resource. To be environmentally sustainable, we have to change the way we handle our resources. We need to use fewer resources by **reducing**. Much of what we dispose of as waste is actually a valuable resource (biological and technical nutrients) that can be captured and used again by reusing, upcycling, or composting.

Biological and technical nutrients are the building blocks of our stuff. **Biological nutrients** are organic materials that can decompose into the natural environment, soil, water, etc. without affecting it in a negative way, providing food for bacteria and microbiological life. **Technical nutrients** are inorganic or synthetic materials manufactured by humans—such as plastics and metals—that can be used many times over without any loss in quality, staying in a continuous cycle.

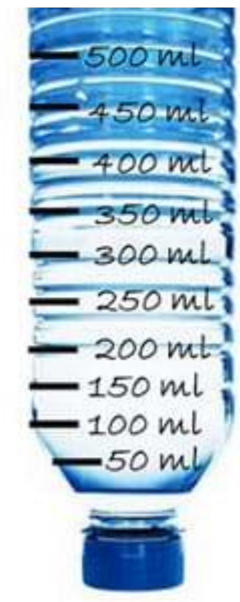
Traditional waste disposal methods, landfilling and incineration, can cause environmental problems such as air and water pollution. If the amount of trash generated by our society continues to rise, future generations will be faced with greater environmental and health problems as a result. Society's linear waste system (cradle to grave design) assumes an endless supply of non-renewable resources. By adopting a cyclical system in which resources are endlessly reused in the production process (**Cradle to Cradle design**) we can save the money, **energy**, and resources needed to extract and transport raw materials, and keep waste out of the landfill.

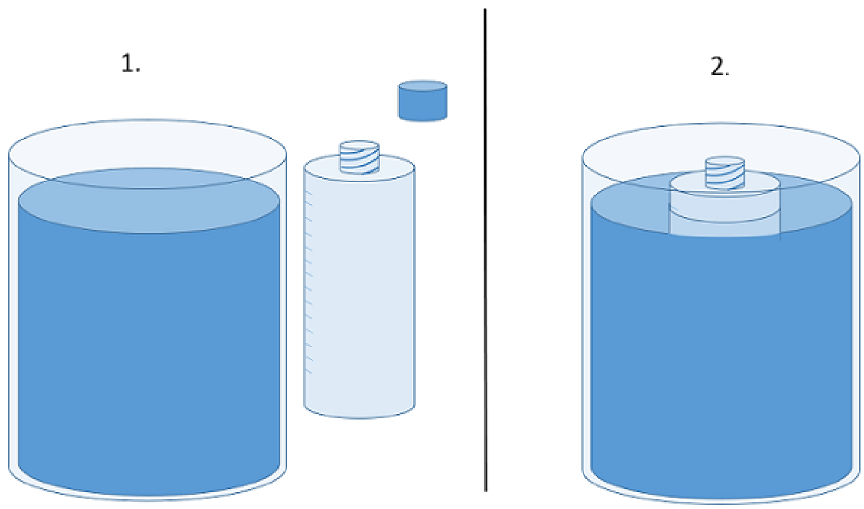
While we still use **fossil fuels** for energy today, they are **nonrenewable energy sources** that take millions of years to naturally replenish and are becoming more difficult to extract. Society is looking for new **renewable energy sources** so that we can **conserve**, or use wisely to avoid waste, those that come from deep within the Earth. Did you know that you can get energy from garbage? There are two ways that we can use our garbage to make energy. In one method, garbage is taken to a waste-to-energy incinerator. These burn the garbage and this process generates heat that can be converted to fuel and electricity. Incineration converts the waste into gas, heat, and ash but also releases toxic chemicals into the environment.

A second method involves the organic garbage (biological nutrients) that we dispose of in landfills. As this garbage decomposes under **anaerobic** conditions (without the presence of oxygen, microorganisms called **archaea** or **methanogens** feed on the organic matter and produce **methane gas** (CH4). This process is known as **anaerobic digestion**. Some landfills are using the methane gas produced by anaerobic digestion to generate electricity; provide fuel for factories, schools, and other facilities; and to produce natural gas. But more often than not methane is leaked into the atmosphere, where it is 25 times more powerful than carbon dioxide at warming the Earth.

We can purposefully utilize anaerobic digestion by building a **biodigester** to produce renewable energy from our food waste called **biogas**. Raw biogas can be used as cooking fuel or further refined to be used in vehicles and for electricity generation. The solid fibrous component of the digested material which comes out in a slurry can be used as organic fertilizer for agriculture. Biogas is one of many forms of renewable energy that we can use to power the world as we eliminate our reliance on fossil fuels and reduce carbon emissions.

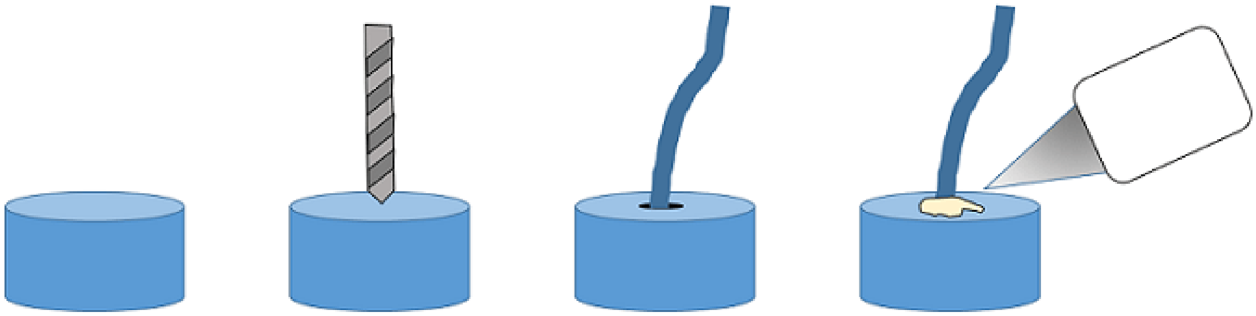
Procedures – Build a Model Biodigester





1. Cut 2.5 cm off the bottom of the small water bottle.
2. With the cap on, invert the bottle so the cap is on the table. Use a graduated cylinder to measure 50 ml of tap water and put the 50 ml of water in the inverted bottle. Mark the water line with a permanent marker and label it "50 ml."
3. Continue to fill the water bottles, 50 ml at a time, marking each new 50-ml water level until the bottle is full. These are the "gas measurement bottles" for the experiment.
4. Cut 1 of the 2-liter bottles in half. Recycle the top; it is not needed for the experiment. The bottom halves serve as water traps to keep the gas in the gas measurement bottles.
5. Fill the 2-liter bottom three-quarters of the way with regular tap water.
6. Uncap each gas measurement bottle and place it within a water bath with the bottle cap side up. Let the bottle fill completely with water.
7. Now let's build our reactors! Take the bottle caps and use a drill to make one small hole in the center of each cap. The hole must be large enough to permit the tubing to slide through it.

8. Cut the tubing into 0.5 meter (~1 foot) sections, enough for 1 sections per digester. Place the end of one section into the cap of the 2-liter bottle used as the anaerobic digester. The tubing should only go into the cap about 2-3 cm (~1 inch).
9. Use hot glue to secure the tubing in place with no air leaks. It is critical to have a tight fit because if any air enters the bottle, the microbes won't be happy and the biogas will escape.



10. Place the other end of the tubing in the hole of a 500-ml bottle cap.
11. Glue the tubing in place. Refer to Figure 4 to see the final experimental setup composed of an anaerobic digester and a gas measurement device.
12. Place 500 ml of pond mud and feedstock in the two liter bottle and add 500 ml of distilled water. Seal the digester using the caps that have tubing attached to them.

Please draw your experimental set up, labeling all components and a brief prediction of what will happen.

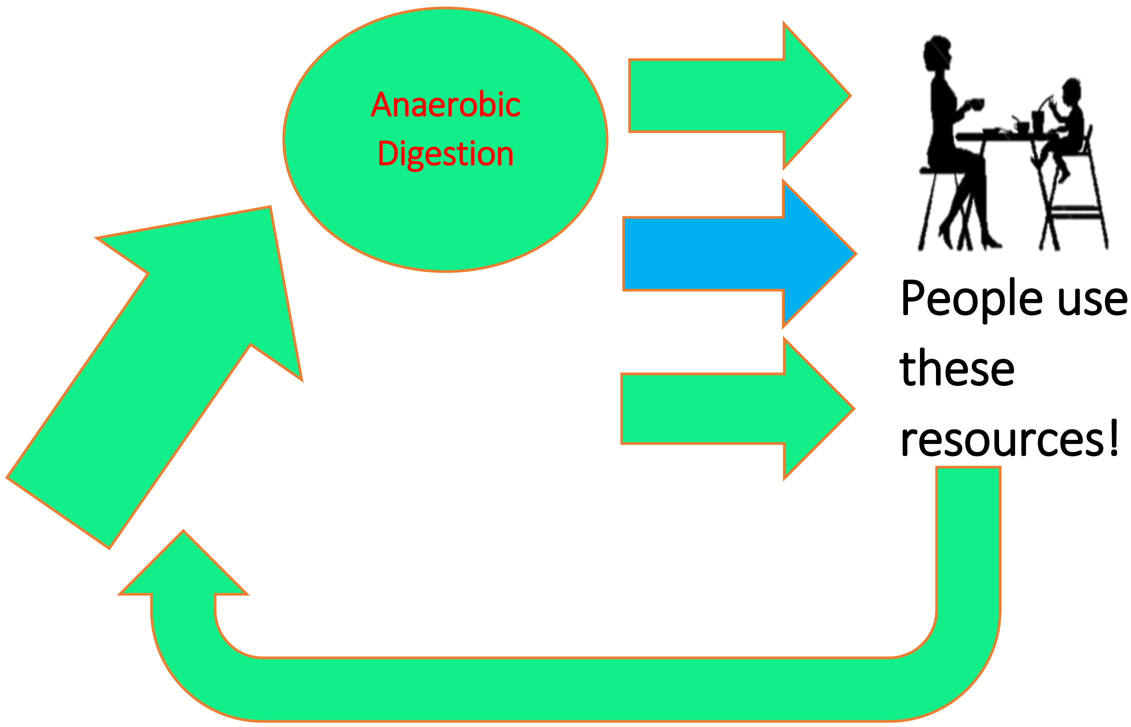
Post Lab Questions

1. **Please some of the actions you can take to promote a zero waste lifestyle**

2. **Please describe the difference between biological and technical nutrients. Provide examples:**

3. **Please describe the difference between recycling and upcycling:**

4. Fill in the blanks in the diagram below:



5. Where does anaerobic digestion happen in nature?

6. How is anaerobic digestion different from (or the same) as composting?

Glossary

- **Archaea**: a domain of single-celled microorganisms with no cell nucleus. Archaea are a major part of Earth's life and may play roles in the carbon cycle and the nitrogen cycle.
- **Anaerobic Digestion**: a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.
- **Biodigester:** A tank which digests organic matter anaerobically and produces methane gas, liquid fertilizer and water.
- **Biogas:** A mixture of different gasses produced from the breakdown of organic matter in the absence of oxygen.
- **Cradle to Cradle Design**: is a **biomimetic** approach to the design of products and systems that models human industry on nature's processes viewing materials as nutrients circulating in healthy, safe metabolisms.
- **Fossil Fuel:** a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.
- **Methanogens**: Archaea that produce methane as a metabolic byproduct in hypoxic conditions. They are common in wetlands, where they are responsible for marsh gas, and in the digestive tracts of animals such as ruminants and humans, where they are responsible for the methane content of belching and flatulence. Methanogenic archaea populations play an indispensable role in anaerobic wastewater treatments. Others are extremophiles, found in environments such as hot springs and submarine hydrothermal vents as well as in the "solid" rock of the Earth's crust, kilometers below the surface.
- **Non-renewable Resource:** A resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time-frames.
- **Renewable Energy:** is **energy** that is collected from **renewable** resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.
- **Upcycling:** Also known as **creative reuse**, upcycling is the process of transforming by-products, waste materials, useless, or unwanted products into new materials or products of better quality or for better environmental value. Upcycling is the opposite of **downcycling**, which is the other face of the **recycling** process. Downcycling involves converting materials and products into new materials of lesser quality. Most recycling involves converting or extracting useful materials from a product and creating a different product or material.
- **Zero Waste:** Zero Waste is a goal to guide people to emulate sustainable natural cycles, where all discarded materials are resources for others to use. Zero Waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that may be a threat to planetary, human, animal or plant health.

Sources

"Don't Throw Me Away: A Zero Waste Curriculum" by Seven Generations Ahead

https://en.wikipedia.org/wiki/Upcycling

"Biogas As A Source of Energy, Lesson 3" by Heifer International – www.heifereducation.org

"The Zero Waste Project" – www.resourcefulschools.org

https://en.wikipedia.org/wiki/Cradle-to-cradle_design

https://www.teachengineering.org/activities/view/usf_biorecycling_lesson01_activity1

Name: Date:

Anaerobic Digestion Data Sheet

Microbe Source:

Start Date:

Height Measurements

Date	Biogas Volume
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Observations/Notes: