Answers will vary. We have provided examples of possible answers and ideas of what to look for in students' thinking.

Aquaponics in a bottle!

Name: Teacher Guide _____ Date: _____

Instructions:

1. Gather your materials to build your experiment:
    a. One clear, two-liter plastic bottle (soda, juice, or iced tea containers work well)
    b. Extra container to hold water for water changes
    c. Serrated bread knife and cutting board, or scissors
    d. Aquarium gravel, or small rocks (enough for about 2 inches at the bottom of your bottle)
    e. Drill with small drill bit (or alternative tool to poke a hole in the bottle cap for plant roots to go through)
    f. Water
    g. One aquatic organism: One small fish (a snail and/or shrimp may also be used)
    h. Fish food (can be purchased from a pet store)
    i. Small starter plant or a cutting that has been rooted (herbs like basil grow easily and work well)
    j. Optional: Two skewers for holding the top of the bottle in place
    k. Optional: Aquarium aerator, with tubing and airstone. (You can purchase splitters so multiple tubes with airstones can be divvied to separate aquaria.)

2. Before you begin, answer these questions:
    a. How do scientists study plants and animals in their natural habitats?
    Purposeful observation and record keeping are two of the main tools for studying plants and animals in their natural habitat. Studies often begin after observation of a phenomenon, a change, or something interesting. By regularly observing, scientists are practicing what Hawaiians call kilo, the purposeful watching needed to understand a place. By recording observations, the data can be shared or compared over time.

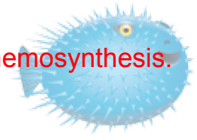
    b. What might be some limitations, challenges, or risks with studies in the natural environment?
    Humans are limited because our senses of sight, smell, sound, etc. are not as well adapted to the environment as the animals and plants that naturally live there. We are also daytime animals, so our studies tend to happen during the day; we know less about what happens at night than we know about daytime activity! With limited resources, it is also impossible to watch and observe all parts of the environment. So, researchers have to make decisions about what they can study and how to design their observations to provide the most meaningful information.

    c. What is the ethical treatment of living things? How will you ensure your animals are being treated ethically?
    The ethical treatment of living things is a moral consideration of how nonhuman living things should be treated. Look for students to thoughtfully consider how they will ethically treat their animals and plants and what procedures they will follow if their animals stop doing well and/or when they are done with their experiments and no longer want to keep their animals and plants.

    d. Why do animals, including humans, eat things?
    Animals eat things to get energy and nutrients. Animals need to eat because they cannot use the energy from the sun (or other sources like sulfuric hot springs) to make food or body matter. Some animals, however, do have symbiotic relationships with plant-like organisms that can photosynthesize (think reef building corals and their photosynthetic symbionts).

    e. Do plants eat?
    Plants use the sun's energy to photosynthesize and thus they do not need to eat. However, some plants eat and photosynthesize. Some examples of carnivorous plants include the venus fly trap, the pitcher plant, and some orchids that digest bees as they try to pollinate the flowers.

    f. What is a producer? Consumer? Decomposer?
    A producer uses energy from the sun or chemicals to make biomass through photosynthesis or chemosynthesis.
    - like phytoplankton, plants, or chemoautotrophic bacteria
    A consumer needs to eat to get energy from plants or by preying on other animals.
    - like animals and humans
    A decomposer is an organism that breaks down dead or decaying organisms. - like soil microbes and fungi.



NOTE *The procedural steps call for letting your water sit, rocks soak, and rinsed plant roots soak for 24 hours. You can do all these steps at the same time before you start constructing the aquaponics-in-a-bottle.*

Build your aquarium!

3. Prepare your water by allowing it to sit in a container exposed to the air for 24 hours. This will allow the chlorine to evaporate. (Chlorine is used to keep tap water from becoming contaminated with algae or bacteria). You can also use commercial drops to treat your water before using it in your aquaponics system.

4. Rinse your aquarium gravel and allow it to sit in water for 24 hours to remove any toxins.

5. Rinse and scrub the two-liter bottle with clear water to get rid of any residue inside and to remove any labels from the outside. Do not use soap!

6. Cut off the bottle top at the shoulder (where the bottle tapers).

Note: cut the bottle so the lower aquarium portion will have a bit of curvature at the top.

7. Add a layer of small aquarium rocks to cover the bottom two inches. Rocks are important for two reasons:

a. Rocks provide a surface for good bacteria to live on. These bacteria help to convert the fish waste into nutrients that are usable by plants.

b. Rocks keep the water clearer by holding fish poop and uneaten food particles, which keeps them from floating in the water.

8. Fill the bottle with prepared water. Leaving about an inch and a half of space at the top.

Get your plant zone ready!

9. Use a drill to make a hole in the bottle cap. The hole should be big enough to pull the plant roots through, but small enough that the plant stem will not slide through.

10. Prepare your plant roots to pull through the hole in the bottle cap.

a. Rinse the roots. This is especially important if you are using a plant that was in dirt.

b. We recommend soaking your plant roots in clean water for 24 hours.

11. Pull your plant roots gently through the hole in the bottle cap.

Note: Some of the roots will break off. That is okay!

12. Set your plant zone on top of your aquarium, or a another water source, while you continue to set up your aquaponics-in-a-bottle.

13. If the bottle top doesn't rest on the brim of your aquarium, you can use wooden skewers as support beams.

a. With help from a teacher, poke two holes on opposite sides of the bottle top and slide wooden skewers through them. Allow them to protrude about an inch on each side. Do this on both sides. Rest it on top of the bottle aquarium.

Add your fish!

14. Make sure your water has been sitting out and rocks and roots have soaked in clean water for 24 hours.

15. Add your fish to the aquarium!

16. You may add another small creature, like a snail, that you think would be a good fit for the ecosystem. *Note: Keep in mind this is a very small aquarium, so don't add very much. One small fish and one snail are a good amount!*

17. You may add an aquarium decoration if you like (but make sure it is non toxic and has rested in clean water for 24 hours).

18. If you have an aerator, position your aquarium near a plug and plug in the aerator. Place the airstone in the aquarium.

19. Put the plant side on top of the aquarium.

20. Make sure the water level is correct.
    a. Your plant roots should be in the water, but there should not be standing water inside the plant dome.
    b. Add or pour out water as needed to get the right level.

21. Your aquaponics-in-a-bottle is now complete!

Care for your ecosystem!

**NOTE* In nature, the cycling of matter between producers, consumers, and decomposers allow the ecosystem to thrive without external input. However, since this system is small and will likely not represent all aspects of a natural ecosystem, you will still need to feed the fish and water the plant to ensure they are getting enough energy.*

22. **FEEDING**: Drop a few flakes or pellets (depending on food choice) on the surface of the water to feed the fish few days (every 2 or 3 days should be fine).

23. **CLEANING**: You will need to replace about 1/3 of the water every 1-2 weeks as needed. This will prevent algae buildup and ensure enough oxygen is available (The plants will contribute to the oxygen available).

    a. Prepare replacement water the day before, allowing it to sit out for 24 hours to evaporate any chlorine.
    b. Remove the top and scoop out about 1/3 of the water using a cup (a soup ladle works well). Be careful not to scoop the fish with the water!
    c. If there is algae build up on the exposed walls, you can wipe it off with a paper towel or clean sponge to prevent overgrowth.
    d. Pour in fresh water slowly so as not to stir up any loose particles.

24. Make observations of your system over time and answer the questions on your worksheet.

25. Engineer changes to your system! Aquaponics systems benefit from regular attention and tinkering. Do not be afraid to change things in your system as time goes on!

Activity Questions

1. Match the vocabulary words with their definitions below. Then use the information to answer the activity questions. Students can match definition letters with vocabulary, or draw connecting lines.

Vocab Word	Answer	Definition
Matter	D.	A. An organism requiring food, which it gets by eating other organisms.
Consumer	A.	B. An organism, often bacteria, fungus, or invertebrate, that breaks down waste from other organisms.
Decomposer	B.	C. Organisms that use energy from the sun and matter in air and water to grow.
Primary Producer	C.	D. Any substance that has mass and takes up space by having volume.

2. What role does your plant play in making food from matter in your ecosystem-in-a-bottle? The plant uses energy from the sun and carbon from the air (matter) to make plant biomass. The plant also incorporates nutrients from the fish and fish food into its biomass. (These nutrients are also made of matter, but they contribute much less to the volume of the plant in comparison to the carbon that plants get from the air.)

3. What role does your fish/snail play in moving matter your ecosystem? The fish eats food that we feed it. We also see the fish eating the plant roots. The snails eat algae that grows on the tank. Both the fish and snail poops after digestion. The poop contains nutrients and organic (carbon-containing) food not used up by the fish or snail.

4. What role does the bacteria living on the rocks play in recycling matter in your ecosystem?

   Bacteria in the tank then use the energy from the fish and snail poop to help recycle nutrients from the poop into nutrient forms that are useful to the plants.

5. Which organism in your ecosystem is a:

   a. Primary producer?

      The plants and also the algae that starts growing on the sides.

   b. Consumer?

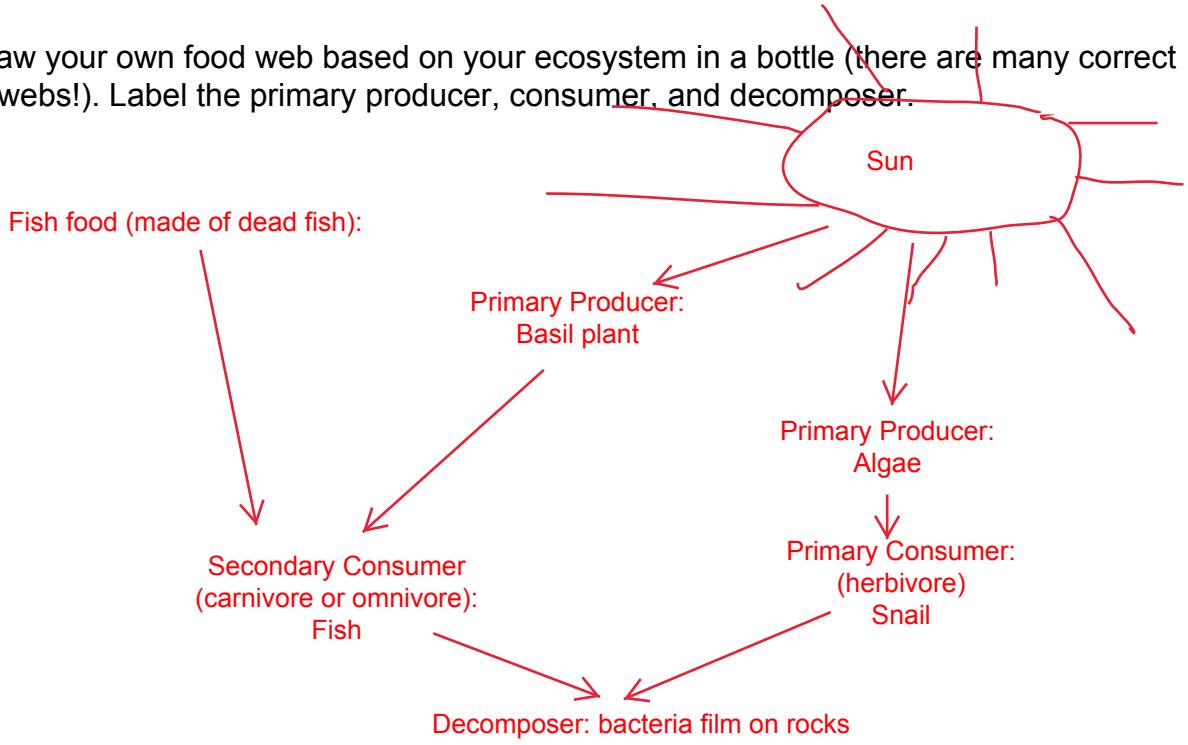
      The fish and the snail.

   c. Decomposer?

      The bacteria that mostly live on the surfaces of the rocks.

6. How do the organisms in your ecosystem work together to recycle matter and produce food? Some of them produce food from matter in the air or water (plants and algae), some eat food matter (fish and snail), and some recycle food (bacteria).

7. Draw your own food web based on your ecosystem in a bottle (there are many correct food webs!). Label the primary producer, consumer, and decomposer.



8. What might happen if a higher level predator was introduced to your ecosystem (such as a crayfish, large fish, or large frog)? A higher level predator might eat the lower level predators (the fish and the snail). This might lead to a more complex food web in the aquaponics system (if there are enough fish and snails for the predator to keep eating). However, since our system is very small, there is only one small fish to eat, so a larger predator would probably not do well in the long-term,

9. Is there evidence of any other plant life in the aquarium? (Hint: It is possible that microscopic freshwater algae may have grown, and if it becomes dense enough may appear either as a greenish film, or perhaps a greenish hue in the water.)

The sides of the container get greenish if it is left and not cleaned for many weeks. This is a sign of algae growing in the water. The nutrients from uneaten fish food, from fish/snail poop, and from the plant roots being decomposed all contribute nutrients in the water that help the algae grow. The algae use carbon from carbon dioxide in the water to grow their biomass. The algae also photosynthesizes to make food.

10. How are models beneficial to scientists when studying plants and animals?

Models represent systems or events to help scientists understand the natural world. Models can help scientists communicate their ideas, understand processes, and make predictions.

11. How could you improve your design for a future aquaponics system?

Look for students to have ideas about the type of container, the type of plant, the type / amount/ number of fish or other organisms, the type of food, the water changing regime, etc. This is the place where their engineering skills can shine!

Encourage students to also report on how they manipulated their aquaponics system as they built and used it. Did they follow the directions exactly, or did they need to engineer changes based on materials they had available?