Hydroponics to Aquaponics!

Name: Teacher Guide ______________________________ Date: ____________________

Instructions:

1. Gather your supplies to build your hydroponic system:
    a. Tank for water (or other clear, large container)
    b. Plastic basket for plant (should have holes so water can circulate the roots of the plant)
    c. Wooden dowel (x2 that are long enough to span more than width of the tank)
    d. Substrate for inside the tank (e.g. Sand (washed), Fish tank rocks)
    e. Root structural support (e.g. cinder, gravel, wood fibers, perlite, vermiculite, pumice or grow stones)
    f. Larger rocks for tank adornment
    g. Small plant for hydroponic growth (herbs like basil grow easily and quickly)
    h. Small plant in larger pot for growth in soil (herbs like basil grow easily and quickly)
    i. Aerator and airstones
    j. Nutrients (e.g. nutrient additive such as MiracleGro. Tomato plant food will do the trick).
    k. Optional (but very helpful!): Magnetic glass cleaner to remove algae
    l. Optional: pH test kit
    m. Ruler
2. Eventually, you will need the following supplies to convert it into an aquaponic system
    a. Guppies, snails, and/or shrimp
    b. Aquatic plant
    c. Optional (but very helpful): filter (can be purchased online or at local pet shop)

Build your hydroponic system

3. You will compare plants grown hydroponically to those grown in soil.

**NOTE* Hydroponics is the method of growing plants in water (without soil). In comparison, Aquaponics is a system that combines aquaculture (the growing of aquatic animals, like fish, snails, clams, etc.) in combination with hydroponically grown plants.*

4. To prepare, replant one of your small plants into a larger pot so that it has space to continue to grow in soil.

5. You will be measuring your plants' growth and recording your results in the data table on your worksheet. Choose a consistent method to measure, for example:
    a. Place the bottom of the ruler at the base of the plant and measure to the tip of the main stem.
    b. Count the number of leaves, or choose a leaf to measure each time.

Prepare your tank

6. Rinse the tank substrate with warm water a few times to prepare it for your ecosystem. Make sure the tank is clean as well!

7. Find a location for your tank with direct access to sunlight and near an outlet (to plug in the aerator).

8. Layer about an inch or two of the substrate on the bottom of the tank.

9. Fill the tank with water. The water may look cloudy at first while the substrate settles.

10. Place the airstone on the bottom of the tank and plug in the aerator. You can bury it slightly under the substrate.

11. Add nutrients according the the instructions on the packaging and based on the size of your tank.

12. Place your plant growing in soil (from #2) next to the tank so it has access to sunlight. Allow it to grow here for the remainder of the study.

13. Measure the starting height of your soil plant and record it on your worksheet.

Explore hydroponic growth!

14. Now that your hydroponic system is set up, maintain the system and observe plant growth!
    a. Water will evaporate over time, so you will need to refill your container. Every time (or every other time!) that you refill, add more nutrients to keep the plants growing well.

15. Optional: Use your pH test kit to check the pH regularly. This will help ensure your system is stable. Basil likes a pH of about 6.5-6.8, so you can adjust as needed using your pH up or down bottles in the test kit.
Note: If you are making your own nutrient solution rather than using plant food, review Perfecting the pH of your Hydroponic Nutrient Solution.

16. Continue monitoring and measuring your plant growth for your desired amount of time. When you are ready to convert your system into aquaponics, move on to the steps below!

17. Compare these results to the plant grown in soil only.

Update your Hydroponics to Aquaponics

1. 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.

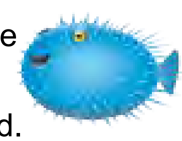
   f. What is a producer? Consumer? Decomposer?
   A producer uses energy from the sun or chemicals to make biomass through photosynthesis or chemosynthesis.
   - like phytoplankton, plants, or chemoautotrophic bacteria
   A consumer needs to eat to get energy from plants or by preying on other animals.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

2. Allow your hydroponics system to cycle out excess nutrients before adding fish - i.e. give the water some time since you last added nutrients. You may also want to change out 1/3 of the water a few days before adding organisms.
3. Review the recommendations for managing care of living organisms (teacher recommendations document).
4. Collect organisms from a local stream if you have permission and safe, easy access.
5. Organisms may include guppies, snails, shrimp, and freshwater plants such as elodea and duckweed, etc.
   Note: If you don't have access or permission to a local stream, organisms can be purchased from a pet shop.
6. Add a few large rocks to the bottom of the tank. These will provide unique structure to the bottom that the fish can swim around.
7. Add the aquatic plants to your tank. Tuck the roots into the substrate. You may need to add a large rock nearby to hold the roots down.
8. Gently add the fish and other organisms to the tank.

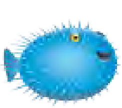
Care for your ecosystem!

NOTE *Your system should be able to maintain itself through the cycling of matter between producers, consumers and decomposers. However, since this system is small and might not represent every trophic level, you will still need to feed the fish to ensure they are getting enough energy.*

1. 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).



2. 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 over night to evaporate any chlorine.
   b. Remove the top (plant or cap) and scoop out about 1/3 of the water using a cup (a turkey baster can also provide easy access to removing water). Be careful not to scoop any 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. Pour in fresh water slowly so as not to stir up any loose particles. Alternatively, if you have a magnetic tank cleaner, use that to wipe the walls regularly to clear the algae.



3. Optional: Monitor pH:
   a. If you keep up with changing the water the pH should stay relatively stable, however biological activity within the tank can cause the pH to fluctuate. Use your pH test kit to check the pH.
4. Additionally, a filter will help maintain the pH. Although the plant roots are doing some filtration, a filter may help to keep your system stable.

Look for students to make thoughtful observations and measurements.

Hydroponic and soil plant growth data sheet

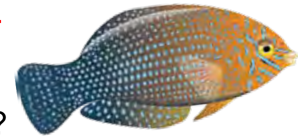
Name: Teacher Guide

Type of Plant: Results will vary by type of plant, quality of soil, and amount of light and water, etc.

Date	Soil Plant Height	Hydroponic Plant Height	Notes and Observations
May 1	6 cm	6 cm	Both plants started off the same height with very amounts of root matter and similar amounts of leaves.
May 6	9 cm	8.5 cm	Both plants are growing, but the one in the soil is growing taller. The one in the hydroponics is growing a lot of roots though, and it seems to be making leaves.
May 11	11 cm	10 cm	The soil plant continues to grow taller, and the hydroponics plant continues to grow in a bushier style more outward and less upward.
May 16	12.5 cm	11.5 cm	The plants grew the same amount in height this time, but they continue to have different growing patterns, with the hydroponics one more leafy.
May 21	14 cm	12.5 cm	Both plants seem to be doing well in their environments. The soil one continues to be taller.
May 26	16 cm	14 cm	The end of our trial shows that the soil plant reached the highest height, but the hydroponics one has more leaves and a bushier look.

Answers will vary. We have provided suggested responses based on our trials.

Activity Questions



1. What happened to your best growing plant during the experiment?

   It was hard to tell which plant was the best growing because the soil plant grew taller but the hydroponics plant made more leaves. The soil plant grew upwards more and had a thicker, sturdier feel to it.

2. Where did your plant get its energy to grow?

   From the sun. Note: the plant did not get energy from the water or from the nutrients, rocks, or soil.

3. What resources did you give your plants?

   I gave my plant sunlight, water, nutrients, and a home (plastic container and rocks to physically support it).
   I gave my soil plant soil and water.

4. Compare the basil grown in soil versus the one grown hydroponically: Look for students to describe the overall plant shape and health.
   a. Describe how your hydroponic plant grew.

      The hydroponic plant grew well, but it grew less in height and less in stem thickness than the plan in soil. However, the hydroponic plant grew more on the sides. It grew more new stems and leaves.

   b. Describe how your plant in soil grew.

      The plant in soil grew taller than the plan in water. The soil plant also appeared to have a thicker stem and be sturdier than the plant in water. But, the soil plant did not grow side branches like the water plant.

5. Collect the class data for plant growth:
   a. What was the class average hydroponic plant growth height (cm)?

      The average hydroponic plant grew 8.5 inches (ours grew 8 inches)

   b. What was the class average soil plant growth (cm)?

      The average soil plant grew 11.25 inches. (ours grew 10 inches)

6. How does your data compare to the class average?

   The class data was similar to our results, we were just a little bit slower in growing than the average.

7. Did the plants need soil to grow? What evidence do you have?

   No, because my plants in water also grew. And, the plants growing in water with nutrients added grew even faster in some ways (like the side stems and leaves) than the soil plants.

8. Why do you think plants normally grow in soil?

   Soil is all around us and has the things that plants need to grow, like nutrients, water and structural support.

9. What do you think soil provides to plants?

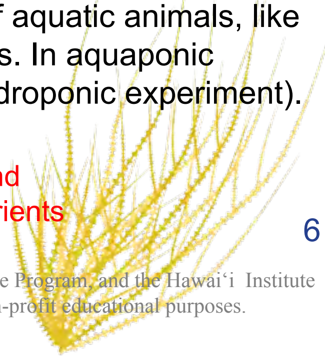
   Soil helps to hold water and provide structure for plants. Soil also contains microbes, like bacteria, and other small organisms like bugs and earth worms, that help aerate the soil (provide access to oxygen) and convert waste from dying plants and animals into nutrients that are useful to plants.

10. How are hydroponic plants surviving without soil?

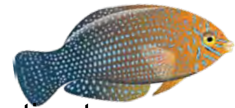
    We are providing nutrients and structure. Hydroponically growing plants takes more human effort, but hydroponics also helps to grow plants quickly in a pest-free zone, which is good for lettuce and tomatoes.

11. Aquaponics is a system that combines aquaculture (the growing of aquatic animals, like fish, snails, clams, etc.) in combination with hydroponicly grown plants. In aquaponic systems, growers do not need to add nutrients (like you did in this hydroponic experiment). Explain why aquaponics systems do not need added nutrients.

    The nutrients in aquaponics systems comes from the animal waste (pee and poop), which is recycled by microbes (like bacteria) and converted into nutrients that the plants can use to grow.



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.)

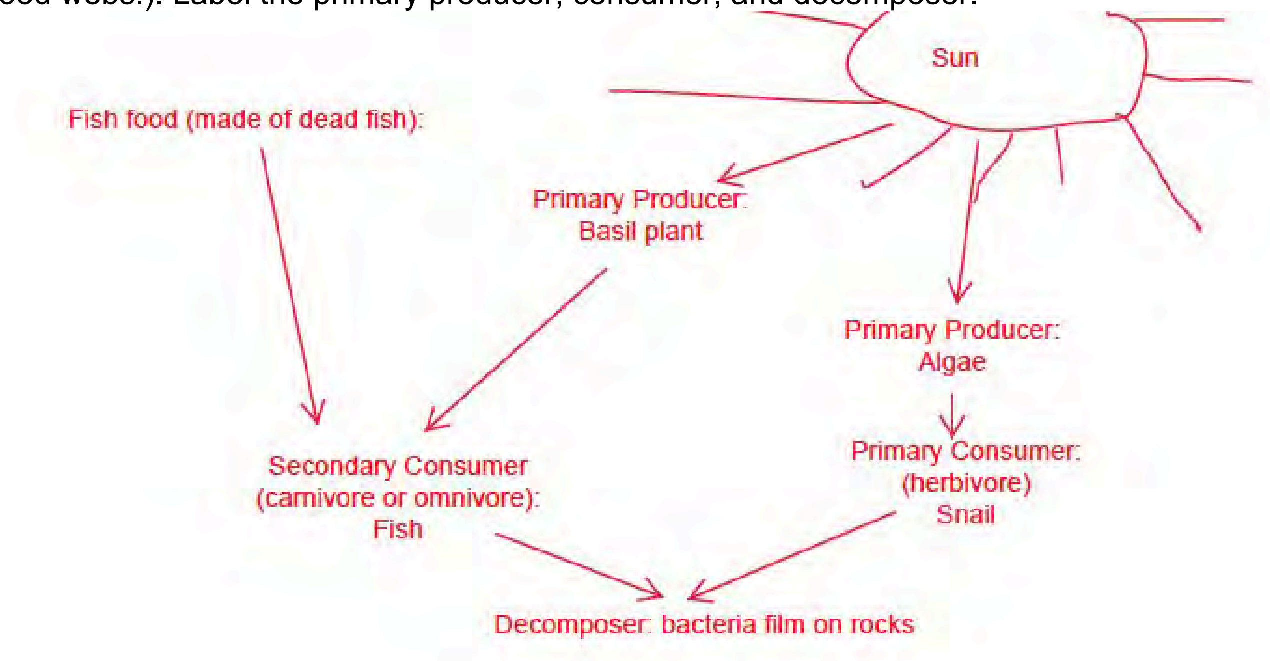
3. What role does your fish/snail play in moving matter your ecosystem? The fish eats food that we feed it. We also see the fish eating the plant roots. The snails eat algae that grows on the tank. Both the fish and snail poops after digestion. The poop contains nutrients and organic (carbon-containing) 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?