# LESSON PLAN 7:

# AQUAPONICS &

# LIVING SYSTEMS

**Curriculum:** Introduction to Biodesign
**Unit:** 3––Biosystems
**Grade Level:** 10th-11th

THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION UNDER GRANT NO. 1723559

TO FIND MORE LESSON PLANS AND TO READ MORE ABOUT THIS CURRICULUM VISIT: BIODESIGNMAKERSPACE.ORG

# Background Information For Teachers

## Overview of this lesson:

*Biosystems are systems or "technologies" found in or inspired by the natural world—systems that are efficient, interconnected, and cyclical. Think of a salt marsh or beaver bond: multiple organisms are contributing to the health and success of that ecosystem, from bugs to mammals to plant life to nitrogen in the nearby soil to microorganisms in the water. "Waste" generated by one organism is repurposed by another to the benefit of the entire system. Each organism matters.*

Human-designed systems do not typically function in this interconnected, sustainable way. Consider systems big and small: the way cities manage and dispose of waste, or the way we heat and cool our homes—these systems end with waste left behind at an incalculable cost to our planet.

We conclude our Biodesign curriculum with this third and last unit, Biosystems, to consider how nature's interconnectedness and efficiency might be applied to the built environment. How could, for example, waste streams be turned into cycles, similar to the way nutrients cycle in a system? How could nature's "technologies" be brought directly into our buildings and public spaces? Students have opportunities to bring in their understanding of biomaterials and biomimicry gained in the previous units and apply them in this one.

Lesson 7 is about direct applications of nature's systems to design. One of the pioneers in this field is John Todd, whose work in using ecological systems for water remediation has created revolutionary means of addressing waste water and contaminated sites around the globe. His work can be found at www.oceanarksint.org , and their PDF of guidelines for creating classroom "eco-machines" is included on our website under "resources".

For our curriculum, we used a subset of eco-machines; aquaponics. Aquaponics combine aquaculture, the cultivation of aquatic organisms with hydroponics, a soil-less means of plant cultivation,which allows for food to be created in areas that might be otherwise food-scarce. In the Biodesign Makerspace, there are functioning examples of that we used to begin this unit and anchor this lesson: three aquaponics systems and a hydroponic green wall.

This lesson could easily expanded to cover many class periods, tying in such topics as organismal biology, food networks, biogeochemical cycling, physics and engineering of water flows, hydraulic head, atmospheric pressure and Bernoulli's equation, as well as additional time allowing for the design and construction of fully functional aquaponics projects.This single lesson serves as an introduction to the benefits and basics of aquaponics, while allowing students to begin ideating on what inclusion of such systems might mean in their homes and communities.

# Standards, Objectives, & Supplies

**Grade Level:** 10th-11th

**Duration:** 2+ hours

**Lesson Concept:** We can directly apply nature's cyclical systems to solve human problems, as with aquaponics and eco-machines.

**Lesson Objectives/ Outcomes:**

1. Understand the mechanics behind a single pump aquaponics system, and how it relates to the flow of materials in the nutrient cycles.

2. Understand that nature's cycles can have direct applications in human systems.

3. Hypothesize ways in which a functional object can be designed in a way that is aesthetically pleasing and user-friendly.

**Instructional Support Materials (if needed):**

- Powerpoint with necessary images + journal prompts.
- LCD projector/smartboard
- How to build an aquaponics system" handout

**Materials + Supplies:**

*Note: If you choose to not use an off-the-shelf system, and instead have students work hands-on with building the piping and bell siphons to show how an aquaponics system functions, it requires more advanced time for assembling supplies than previous lessons. Please reference https://www.instructables.com/id/Make-a-Bell-Siphon/*

***For aquaponics set-up:***
- Bins/tanks
- Tubing

***(continuted on next page)***

## Science / Art Standards

**SCIENCE (Next Generation Science Standards):**

**LS 2A Interdependent Relationships in Ecosystems -** Organisms and populations are dependent on their environmental interactions both with other living things and with non-living factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared.

**LS2B Cycles of Matter and Energy Transfer in Ecosystems -** The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.

**LS2C Ecosystem Dynamics, Functioning and Resilience -** If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem.

**ART (National Core Art Standards):**

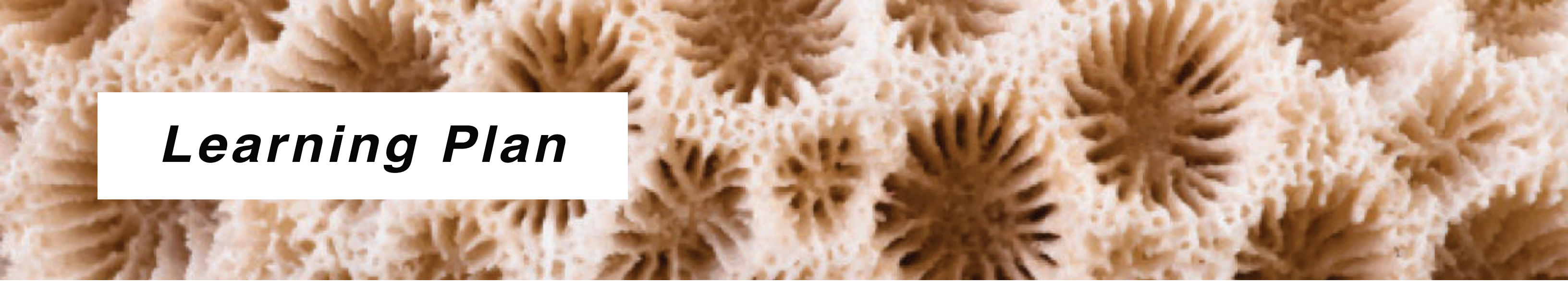
**VA:Re.7.1.Ia** Hypothesize ways in which art influences perception and understanding of human experiences.

# Standards, Objectives, & Supplies

***(continued from previous page)***

- PVC pipe and connectors
- O-rings and/or silicone gaskets
- Pre-cut parts for bell siphons
- Pumps
- Grow medium (e.g., expanded shale)
- Water

***For drawings:***
- Paper (11x17 or larger, 2-3 for each small group)
- Pencils (one
- Colored pencils
- Markers



## Learning Plan

### Stage 1: Motivation

**1. Introduction Lecture: Nature's Cycles.** Tell students: "This unit, Biosystems, is all about natural systems and how those systems are interconnected, efficient loops in which multiple organisms benefit from and contribute to the health of an ecosystem." Briefly review material covered in the last two units and explain to students: "this unit is like the past two in that we will be studying and applying a facet of the natural world to human design. In this unit, we are trying to understand how natural systems might be directly applied in our built environment (like aquaponics), and how the efficiency of natural systems gives us a model for designing for interconnected factors in human systems. Incorporating both into our design thinking can help us live more benignly with each other and in the natural world on this finite planet."

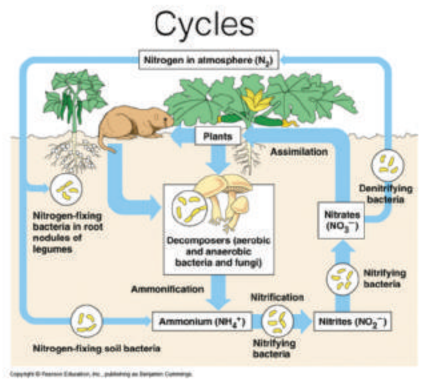



Image: Show students an example of how cycles function in Nature. We showed our students this image of a beaver habitat. Source: Pearson Education

In introducing this unit and the day's activity, show examples of how systems in the natural world function cyclically. For example, we showed students how bacteria, plants, and a plant-eating animal each play a role in the nitrogen cycle. Here, it is also useful to discuss how most human-designed systems do not function in this way—human systems tend to be unsustainable, generate waste, and benefit a small group at the expense of another group. In past classes, students have examined the "plastic problem" and this can be a good example to point to as an "open" human system; we extract non-renewable fossil fuel from the earth to create plastic that is used once or several times, which ultimately ends up in landfills or oceans. Ask students: "What if we borrowed from the sustainable, mutually beneficial nature of natural systems in the built environment? Today's activity will be to create an aquaponics system, which is one way of bringing an efficient, cyclical natural system into our built environment." Explain the workings of aquaponics, referencing a completed and functioning example of the ones they will shortly be putting together. *(15 minutes)*

**2. Hydroponics.** With our students, we began at our hydroponic greenwall to discuss the difference between hydroponics and aquaponics (at the Nature Lab, where we have both hydroponics and aquaponics, the two are often confused and we felt that it was important to distinguish the two, and that each offered distinct approaches to learning about nature's systems). At our hydroponic greenwall, we discussed this method of growth--highlighting the idea that plants do not actually need soil to grow.  We also used the greenwall to talk about the advantages (no need for soil, can exist indoors to the benefit of human health and happiness) and its disadvantages (it requires an input of nutrients, water changes, is water intensive and human-care intensive). If you do not have a hydroponics system in your classroom or school, or do not want to show students how this works by showing printed or projected images, feel free to skip this part. *(10 minutes)*

**3. Aquaponics.** We then moved to our in-classroom aquaponics system to discuss its differences from hydroponics: fish waste is mediated through bacterial action to provide nutrients for plants, water is "cleaned" to recirculate back to fish.  Many off-the-shelf aquaponics systems are available on-line, and plans for our in-class aquaponics model are available on this website under "plans".  This can be set up and operating in advance so that the teacher can reference and students can refer to it as they set up their system.  Alternatively, the class may focus on the concept and set up the classroom aquaponics system as part of the class schedule if additional class time is allowed. *(20 minutes)*

Image: The Biodesign Makerspace' greenwall.

Image: A RISD student tends to the aquaponics system in the Biodesign Makerspace.

## Stage 2: Exploration

1. In small groups, students will learn about the various parts of an aquaponics system, understanding how each part works independently and as a whole.

2. Students will assemble a simple drain and fill system according to directions on the attached worksheet (optional to do in small groups or as demonstration).

3. Students consider the use of the single pump system and the possibility of grow-beds with media and deep water culture options, as well as which type of plants and fish they would like their system to support.

4. Students create two dimensional designs for their "ideal" system, based on who will be using it, and where it will be sited.  Iteration as the result of group discussions is important! *(75 minutes)*

## Stage 3: Reflection

**1. Mini-Critique of Aquaponics Systems.** Students clean up and gather in small groups to discuss the aesthetic design of the aquaponics systems, and it's functionality and usability for their chosen user groups and sites. What about them could be improved? Ask students to brainstorm in groups three things they would improve about the design, either to make it more beautiful, user-friendly, or better integrated into its environment. Students can draw or write. Groups share after fifteen min utes. *(15 minutes)*

Image: A RISD design student sets up an aquaponics system in the Biodesign Makerspace.

**2. Five-Minute Journaling.** Students clean up and return to tables to journal for five minutes. Teacher can pick one prompt for all students to respond to, or students can choose from three prompts. *(Writing: 5 minutes, if desired: 5 minute pair share or group share)*

- Where could you envision aquaponics existing in your home, your school, or your community? In what ways could this system be useful?
- What is the difference between hydroponics, aquaculture and aquaponics? Draw/Write a venn diagram.
- How would you design an aquaponics system in a way that would have the most impact on the most people? Draw.

**3. "So what?" Lesson Recap.** Ask students: What did we do today? Why is it important? Emphasize key ideas covered and larger context for today's learning—for example "Understanding natural systems gives us insight into both how we might benefit from designing natural systems into our built environment, and how the efficiency of natural systems gives us a model for designing for interconnected factors in human systems. Incorporating both into our design thinking can help us live more benignly with each other and the natural world on this finite planet." *(5 minutes)*

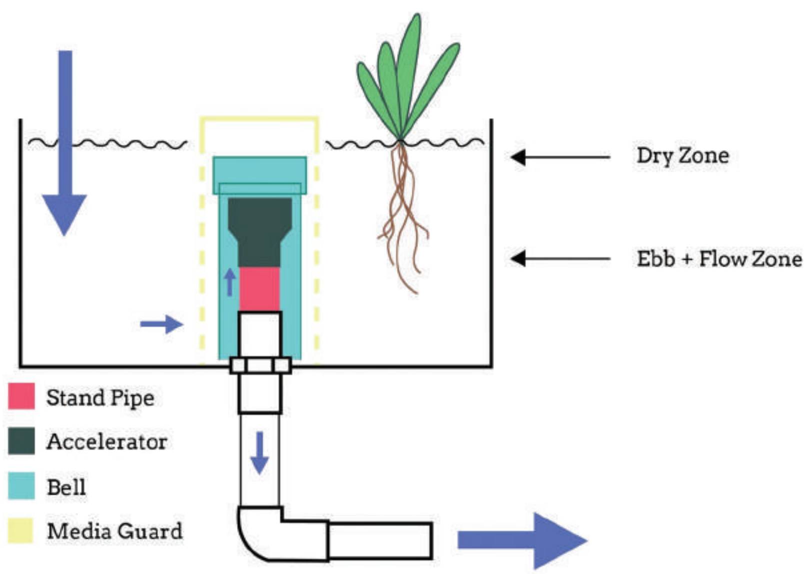
# How To Build An Aquaponics System

Aquaponics systems allow for the cultivation of fish and plants in many environments where it would otherwise be difficult.  This type of closed loop system (a system where waste from one organism is used as nutrients by another)  can provide high yields of protein, vegetables and herbs using far less water than traditional agriculture. Aquaponics systems can also  be modified to fit a variety of spaces, including extending into the vertical.

Aquaponics work by converting waste fish produce into useful nutrients for plants. The removal of waste in this manner maintains clean water for the system without having to use any artificial means.  This is how nutrients cycle in nature, and we will be harnessing that system in our aquaponics units.  The unsung hero in nature and our built systems are the bacteria, particularly nitrifying bacteria that convert ammonia waste ($NH4$) from the fish into nitrite ($NO2$) and then nitrate ($NO3-$), which is then used by the plants for growth.

In this class, we will:
1. Build a simple one pump, drain-and-fill model so you can get a feeling for the mechanics involved.
2. Create a 2D design for a more complex aquaponics unit.

**Building a one-pump drain-and-fill aquaponics system**



# How To Build An Aquaponics System

Procedure:

1. Assemble all pieces as described above, except Grow Bed connector
2. To assemble grow bed connector, place an o-ring over the over the end of each adapter such that it will make a seal when pressed against the bottom of the grow tank. Place the male adapter protruding through inside the tank, and assemble with the female adapter on the outside bottom of the tank. Tighten until just firm (do not overtighten)
3. Place the bell siphon standpipe into the male adapter
4. Place the bell dome over the bell siphon
5. Place medium guard over assembly – optional addition of grow medium in the tank outside the guard.
6. Insert drain pipe into female adapter
7. Arrange tanks so that flow of water from grow tank will drain to fish tank
8. Set up pump in fish tank so that water flows into grow tank.
9. Fill fish tank, and start pump
10. Watch what happens! Do not leave your tanks unattended, at this stage you must make sure that you are with your tanks as long as the pump is running to make sure that the tubing remains flowing into the grow tank

Observations:

What happens when the grow tank fills to its highest level?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

How far above the fish tank can you put the grow bed? See what happens when you lift the water tubing higher – can the pump always push the water higher?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

# How To Build An Aquaponics System

Can you imagine other tanks or grow beds fitting in between the top grow bed and the fish tank? Consider that they can have different dimensions than the tanks given, particularly if you want to have floating rafts rather than grow medium. What might that look like?

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________

**Create a design for a more complex aquaponics unit.**

Now that you have seen how the basic mechanism for creating a drain-and-fill, one pump aquaponics system functions, each team will design an aquaponics unit for use in one of the places you frequent in your everyday life. Consider the following questions, and make sure your design accommodates appropriate responses to them!

What do you want to grow in your system?

______________________________________________________________________________________

______________________________________________________________________________________

What will the plants in your system do for light? Plants either need sunlight, or special grow lights.

______________________________________________________________________________________

______________________________________________________________________________________

Who are you hoping will benefit from having this aquaponics unit? (example: your family, your school, community?), and how will they benefit?

______________________________________________________________________________________

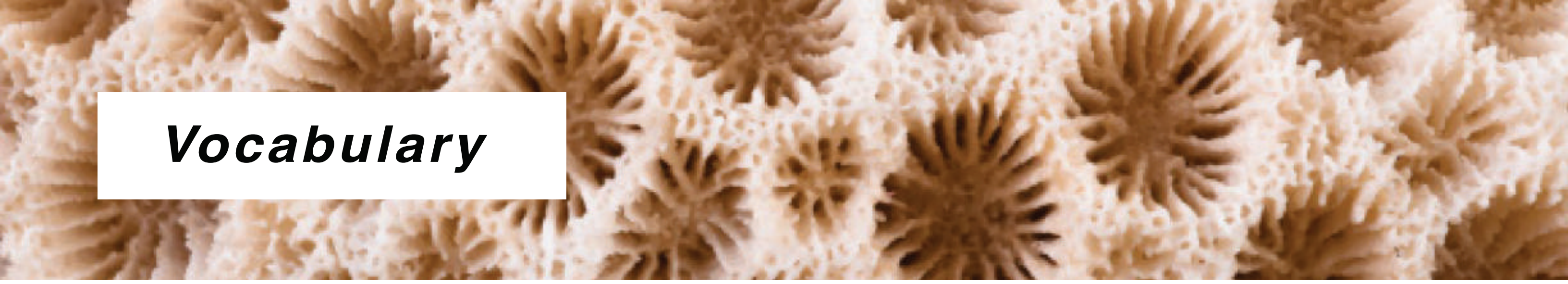
______________________________________________________________________________________

What physical space do you think is available for your system? How might you make it fit (consider unusual tank sizes and shapes, even vertical grow walls)

______________________________________________________________________________________

______________________________________________________________________________________

______________________________________________________________________________________



# Vocabulary

**Terms:**

**Biosystems:** Systems of human design based on systems found in or inspired by the natural world.

**Aquaponics:** A system that combines aquaculture and hydroponics that uses cyclical water flows to mediate nutrient cycling between aquatic animals and plants grown in soil-less grow beds.

**Hydroponics:** A soil-less method of plant cultivation using water supplemented with nutrients.

**Aquaculture:** The culturing (growing) of aquatic organisms, such as fish or shellfish for human consumption.


# Hydroponics:

A soil-less method of plant cultivation using water supplemented with nutrients.


# Aquaponics:

A system that combines aquaculture and hydroponics that uses cyclical water flows to mediate nutrient cycling between aquatic animals and plants grown in soil-less grow beds.


## Biosystems:

Systems of human design based on systems found in or inspired by the natural world.

## Aquaculture

## Aquaculture:

The culturing (growing) of aquatic organisms, such as fish or shellfish for human consumption.