AQUAPONICS LESSON PLAN

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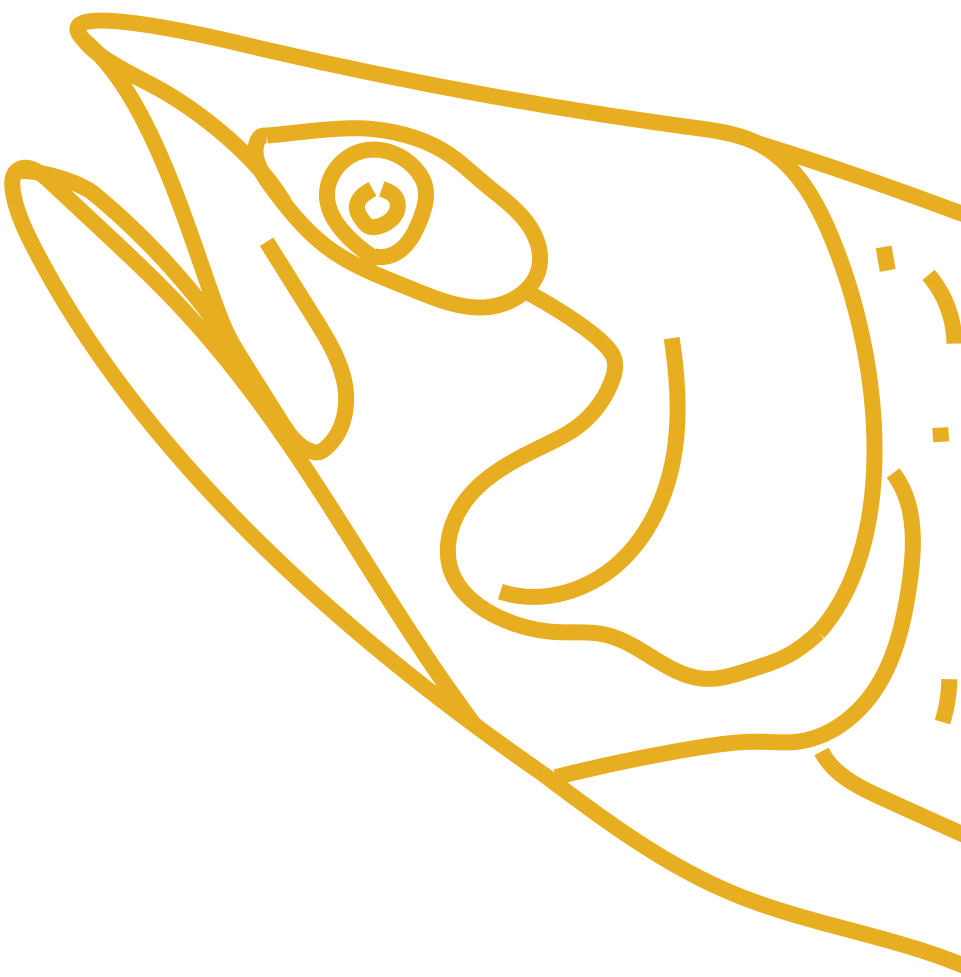


PRICKLY PEAR LAND TRUST

Aquaponics

Location: In classroom

Aim: Why are food production practices not sustainable and how do aquaponics systems address this issue?

Time: 2-2.5 hours

Common Core State Standards: LS2.C

Next Generation Science Standards:

HS-LS2-5, HS-LS2-6, HS-LS2-7, HS-LS4-6, HS-ESS2-2, HS-ESS2-4, HS-ESS2-5, HS-ESS2-7, HS-ESS3-4

Guiding Questions:

What are downstream effects of our local use of the Missouri?
How do we address our unsustainable food production practices?
What are aquaponics systems?

Learning Objectives:

Discuss conservation issues in relation to fertilizer use
Discuss how algal blooms harm marine and aquatic ecosystems
Describe an aquaponics system
Design a simple aquaponics system
Materials: Computers and internet access, poster paper, markers, Mississippi River watershed map, nitrogen cycle handout, student worksheet handout

Lesson Timeline

Note: we will have 2-2.5 hours for this lesson. The discussion and introduction should take no more than 1hr. Leave at least 1 hour, ideally 1.5 hours, to have the students design their aquaponics system. Depending on the class size, the students will need to be broken into groups. No more than 6 students/group.

10 MIN

Students arrive, greet them and introduce yourself

Try to be as engaging as possible. The introduction with the students is what sets the tone for the rest of the lesson. This does not require you to have any special skills, just be friendly and be yourself. It would be great if you included some information about what you do, or did, for work. It is a good opportunity to introduce the students to different careers and does not need to be related to the lesson you are leading.

Ask the students to introduce themselves. Up to you how you want to do this.

10 MIN

Open with a discussion about how they use the rivers in the area

Do they swim, boat, fish? Then discuss if they use the Missouri River. Where does the Missouri end? (if they don't know, tell them) Discuss what a watershed is. Ask them if they know how big the Mississippi watershed is. Show them a map of the Mississippi River watershed.

5 MIN

Ask the students to brainstorm uses of the Mississippi

What pollutants in the Mississippi River watershed might end up in the Mississippi, and then in the Gulf of Mexico?

5-10 MIN

Discuss farming use of nutrients and why they are necessary

This section can be more or less in-depth depending on time and student interest. If you do not want to talk about plant photosynthesis and specifics of nutrient use, just touch on that plants draw nutrients from the soil and that nitrogen and phosphorous are growth limiting nutrients

5 MIN

Ask students if they think all the fertilizer stays on the farm

What happens to it?
Talk about runoff and where excess fertilizer ends up

Lesson Timeline Cont.

5 MIN

Discuss Algal Blooms

Discuss eutrophication and how algal blooms cause it. Point out that this happens in fresh and salt water environments and that it is equally harmful to both of them

5-10 MIN

Tell the students about the dead zone in the Gulf of Mexico

Now that they know about eutrophication and nutrients ask the students why the Gulf of Mexico dead zone is so large

Discuss with students the long term effects of the dead zone, economic, jobs, food supply

Ask the students if they can think of any methods that would stop excess nutrients getting into our waterways

5 MIN

Introduce aquaponics

Give the students a basic overview of the nitrogen cycle because they will need to know it in order to design an aquaponics system.

Tell the students about what they need to consider, including oxygen, nutrients, waste disposal, temperature (air and water), types of fish and plants they want to raise and grow

1 HOUR

Have the students design an aquaponics system

They can design a commercial operation or a home based system. It is up to them, but they must think through the whole system

The students will be given a handout with questions to keep in mind, as well as some information they can review, and a sheet giving some fish examples and the environment they need to thrive

Each group will be given a sheet of paper and will actually draw out the system they come up with

The students will use the internet to get more information if they need it

5 MIN

End the lesson with a discussion about each groups system

This is an opportunity for the students to give constructive criticism, but it is important that you the leader make sure it is constructive and positive

Give each group the opportunity to explain their thinking and see if they find any

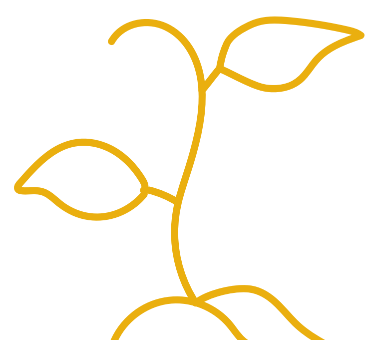
Background Info

Plant Nutrients and Farming Practices

Food production is an essential part of our lives. Without food we cannot survive. But the current way we grow and raise food in the United States causes harm to the natural ecosystems that many species, including us, rely on. In this lesson we are going to discuss the consequences of excess nutrients in our waterways using the Mississippi River and the Gulf of Mexico as a case study. We will then end by discussing closed loop farming practices and design aquaponics systems with the students.

Just like humans, plants need nutrients to grow. Using photosynthesis, plants have the ability to use sunlight, carbon dioxide, and water to store energy. However, plants cannot survive solely on photosynthesis. They need many other nutrients in order to photosynthesize as well as perform other processes. Plants draw nutrients out of the soil through their roots, and the three main nutrients they need are nitrogen, phosphorous, and potassium. Nitrogen and phosphorous are growth limiting nutrients for plants, or they are in a natural ecosystem.

This is a problem for farmers because they need their crops to grow quickly every year in order to make a profit. That is where fertilizers come in. Two of the main ingredients in fertilizers are nitrogen and phosphorous. Fertilization allows farmers to grow their crops faster and bigger, even when the soil does not naturally have enough nitrogen or phosphorous to support the crops.
Fertilizers are generally a good thing; they allow farmers to grow crops with higher yields to feed the population. However, the excess fertilizer that is not used in crops is often washed by rain or floods into waterways. And just like terrestrial environments, nitrogen and phosphorous are limiting nutrients in aquatic ecosystems. Because terrestrial plants normally use most of the nitrogen and phosphorous before it can be washed into waterways, algae growth is limited. However, with the use of fertilizers, as well as run off from animal waste, sewage treatment facilities, and discharge from industrial chemical facilities, the amount of nitrogen and phosphorous in waterways has increased significantly. Because there is no limiting factor for algae growth, we are seeing an increase in algal blooms across the United States in slow moving rivers and stream, ponds, lakes, and the ocean.



Plant Nutrients and Farming Practices

Algal blooms look gross but are they really a problem? Turns out algae blooms cause significant problems both to human health and to ecosystems. Some algal blooms are toxic to humans and can have effects ranging from a rash to neurological effects that can result in death. So if you see an algal bloom on a body of water, do not enter it and do not let your pet drink from it because some algae can be harmful to animals as well.

For ecosystems, algal blooms can have devastating consequences. Algal blooms create an effect called eutrophication. When algae grow out of control they create a layer on the surface of the water that makes it impossible for sunlight to penetrate. Many plants and organisms that live in both fresh and salt water need sunlight to grow. The first consequence when algal blooms occur, is that those organisms cannot photosynthesize because the algae block the sunlight from penetrating into the water column.

The most serious consequence is that it creates an anoxic environment, meaning the water becomes depleted of oxygen. Under normal conditions algae photosynthesize and produce oxygen, but under low light conditions they produce more CO2. Then when the algae and other plant life die from lack of sunlight, they decompose. Decomposition processes use oxygen and produce CO2. This contributes to an anoxic environment that fish and other marine and aquatic organisms cannot survive in. Just like terrestrial organisms, aquatic and marine organisms cannot survive without oxygen. When these algae blooms happen, massive die outs can occur.

Marine Specific Consequences

The excess production of CO2 also has an additional consequence of lowering the pH of ocean water, making it more acidic. When CO2 mixes with water it forms carbonic acid, which can then become carbonate. Shelled organisms pull calcium out of the carbonate molecules in the water to create their shells. However, when the pH is low enough, the free hydrogen ions in the water bind to the carbonate, forming bicarbonate ions, which make the calcium unavailable to shelled organisms. This decreases growth rates of these organisms and impacts their health. When the pH is low enough, hydrogen ions will pull the calcium out of shells, causing the shells of marine organisms to weaken, making them more vulnerable to predators. In extreme cases, their shells fully break down. Without shells, organisms like clams, oysters, and mussels cannot survive.

Dead Zones

A dead zone is where eutrophication has made a large area of the ocean so low in oxygen that most or all organisms cannot survive. The largest dead zone in North America, and the second largest in the world, is in the Gulf of Mexico and is caused by nutrient rich water flowing into it from the Mississippi River. The Mississippi River watershed covers most of the contiguous United States, everything east of the Rocky Mountains, including Montana. The Missouri River is one of the tributaries of the Mississippi, which means that any nutrients or pollution in the Missouri will end up in the Gulf of Mexico and contribute to the dead zone.

The dead zone in the Gulf of Mexico shrinks and grows seasonally in relation to agricultural practices in the Mississippi River watershed. Studies in the last few years showed that the dead zone covered 8,776 square miles. This is a problem because the Gulf of Mexico is important for the region's economy, for food resources, and for ecological habitat. Each year the Gulf of Mexico generates billions of dollars in revenue through commercial fishing, sport fishing, and recreating. Fast, free-moving species like many large fish can often remove themselves from areas of eutrophication, but organisms that are slow moving or cannot leave their habitat, do not have the ability to leave an area if the oxygen levels drop. Coral reefs in particular are especially vulnerable. Low oxygen and lower pH stress the corals and cause bleaching events, and because so many organisms rely on coral reefs, it causes a ripple effect through the ecosystem. In a dead zone, sensitive species die first, lowering the biodiversity of the ecosystem. The species that remain and survive are put under a lot of stress and grow much more slowly. This then has an effect on the fisheries. Fishermen catch fewer and smaller fish, crustaceans, and bivalves, which decreases the available seafood and increases the cost for consumers.

Mitigating Eutrophication

Most of us who live inland rarely think about how our actions might be impacting marine ecosystems, and by extension, the food resources and economy of the whole United States. As we have seen, our practices inland can have devastating consequences for these ecosystems. So what can we do about it? We still need farms to grow crops, these also are important food and economical resources.

One of the changes that farms can make to reduce their impacts on aquatic and marine ecosystems is to decrease the amount of fertilizer to the smallest amount possible. This reduces the nitrogen and phosphorous introduced into waterways through runoff. However, this merely reduces the impact and does not entirely get rid of the negative consequences. In response to this problem, farmers and scientists around the world are beginning to look into closed-loop farming systems in order to completely eliminate the negative side effects of farming.

The most promising closed-loop farms are what we call aquaponics. Aquaponics is a method of farming that combines aquaculture, which is growing and raising fish, with hydroponics, which is growing plants without using soil. In addition to the problems we discussed, farming uses a huge amount of water. This is because when you water a crop, a significant portion of that water seeps into the soil without the plants using it and is wasted. Hydroponics looks to reduce the amount of water it takes to grow crops by growing plants in nutrient rich water instead of soil. However, individually both of aquaculture and hydroponics have shortcomings.

The purpose of aquaculture is to reduce the amount of wild fish we catch in rivers and in the ocean. Humans around the world are fishing so many wild fish that these fish stocks are getting smaller every year because they cannot reproduce fast enough to replenish the population. There are a few problems with aquaculture though. The two biggest are the food source and excess food. Aquaculture seems like a good idea, raise your own fish and do not deplete the wild stocks. However, most commercially available fish food contains wild fish as a source of protein, which defeats the purpose of aquaculture. Many aquaculture facilities over feed their fish and the excess feed negatively impacts the natural ecosystems around the aquaculture facilities. This can be particularly harmful for marine ecosystems because the excess feed drops to the ocean floor beneath the fish pens, smothering marine plants and organisms.

Hydroponics works by suspending or floating plants in nutrient rich water, and significantly reduces the amount of water used to grow a crop. In traditional farming, it can take 10-16 gallons of water to grow one head of lettuce, while in a hydroponic system it can take 4-5 gallons to grow one head of lettuce. However, in a hydroponic system, you still have to add nutrients into the water as the plants deplete it.

The goal of aquaponics is to create a closed-loop farming system that uses the least amount of resources to raise plants and fish for consumption. The biggest challenges aquaponics systems face are waste recycling, water movement, and providing enough nutrients. To understand how an aquaponics system works we need a basic understanding of the nitrogen cycle.

Nitrogen Cycle Overview

Introduction

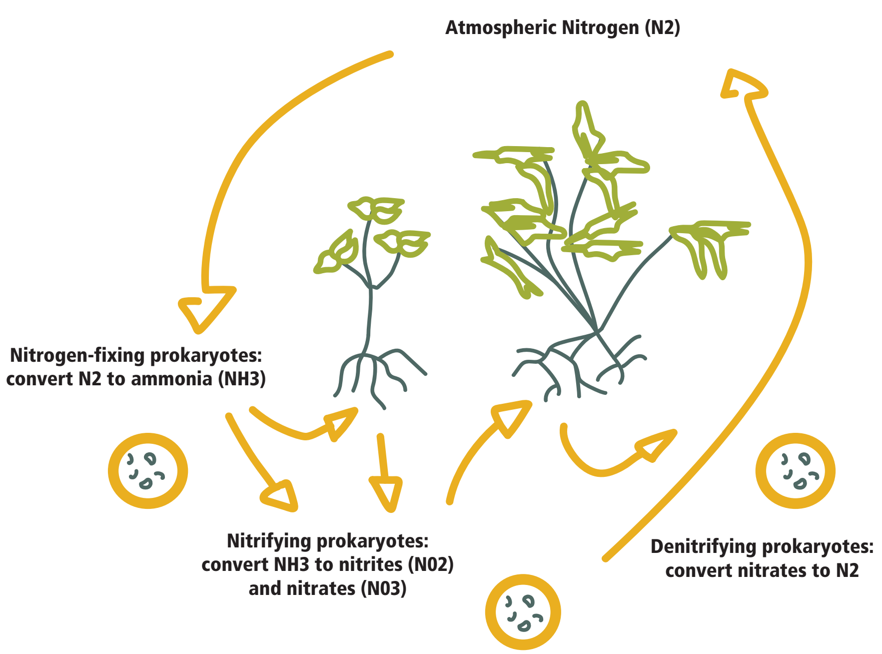
Nitrogen is everywhere! In fact, N2 gas makes up about 78% of Earth's atmosphere by volume, far surpassing the O2 we often think of as "air".But having nitrogen around and being able to make use of it are two different things. Your body, and the bodies of other plants and animals, have no good way to convert N2 into a usable form. We animals—and our plant compatriots—just don't have the right enzymes to capture, or fix, atmospheric nitrogen. Still, your DNA and proteins contain quite a bit of nitrogen. Where does that nitrogen come from? In the natural world, it comes from bacteria!

Bacteria play a key role in the nitrogen cycle

Nitrogen enters the living world by way of bacteria and other single-celled prokaryotes, which convert atmospheric nitrogen—N2—into biologically usable forms in a process called nitrogen fixation. Some species of nitrogen-fixing bacteria are free-living in soil or water, while others are beneficial symbionts that live inside of plants.

Nitrogen-fixing microorganisms capture atmospheric nitrogen by converting it to ammonia—NH3 which can be taken up by plants and used to make organic molecules. The nitrogen-containing molecules are passed to animals when the plants are eaten. They may be incorporated into the animal's body or broken down and excreted as waste, such as the urea found in urine.

Nitrogen doesn't remain forever in the bodies of living organisms. Instead, it's converted from organic nitrogen back into N2 gas by bacteria. This process often involves several steps in terrestrial—land—ecosystems. Nitrogenous compounds from dead organisms or wastes are converted into ammonia—NH3—by bacteria, and the ammonia is converted into nitrites and nitrates. In the end, the nitrates are made into N2 gas by denitrifying prokaryotes.



DESIGNING AN AQUAPONICS SYSTEM

Designing an aquaponics system

A traditional aquaponics system often has a pool with fish in it and plants suspended above the water so that their roots are submerged under water. Another method is to have the fish in a separate pond, then pass the water through an area where bacteria convert the fish waste to usable nitrogen – N3 - for the plants, and then the water is pumped to the plants before being returned to the fish. There are a number of different design methods but there are several criteria that need to be monitored and accounted for when designing your system.
Temperature

Fish are ectothermic, meaning their body temperature is determined by the temperature of the water they live in. Different fish have different temperature criteria so, when designing your system, you need to pick a fish that can thrive in the water temperature. An additional consideration is that the colder water is, the more dissolved oxygen can be in the water.
Air temperature will also need to be taken into consideration. What type of facility will be used in order to maintain a particular climate and temperature for both the fish and the plants
Oxygen

The system needs to have enough oxygen for both the fish and the plants. Aerators can be used to add oxygen to the system or, if you have enough space, you could design a waterfall system that aerates the water for you. There also has to be a mechanism that keeps the water moving continuously. There could be pumps that move the water through the system, or it could be mostly gravity based, where the pump just moves the water from the lowest to the highest point in the system.

Nitrogenous waste
High ammonia concentrations in water are harmful to fish. Aquaponics systems need a filter technique that converts the fish waste into a form that plants can use. As we learned in the nitrogen cycle, forms of bacteria can do this for you. There needs to be some sort of biofilter mechanism built into your system. Also take into consideration the solid fish waste and how you filter that out

pH
pH is the level of hydrogen ions in your water. It is important to check your water source pH and ensure it is a safe range (best 6.5-8.5) as well as monitor it when you get your system running.
Fish food
Some species of fish can survive mostly on algae and plants but still need a source of protein. Fish food is a good source, but, if you want to make a fully closed circuit system, consider worms or bugs that you can grow yourself.

Student Handout Information

Finding the Right Fish for Your Aquaponic Tank

Aquaponics, a farming method that combines hydroponics (growing plants without soil) and aquaculture (raising fish in a closed system), is poised to become the Next Big Thing in sustainable agriculture. Indoor and backyard small-scale aquaponic systems--like those found at a school--are estimated to number in the thousands, and larger operations, like hobby and commercial farms, are becoming more common as well. The key feature of an aquaponic system is the symbiotic relationship between the fish that produce nutrient-rich waste, and the plants, which filter and use the nutrients for growth. Finding the right type of fish for your tank is one of the most crucial elements of the system. Water temperature: the Goldilocks Principle

The first consideration when you are choosing a fish species is the temperature of the water in your tank. If your system is indoors in a classroom, or outdoors in a warmer climate, you will want a fish that thrives in warm water, such as tilapia. If your tank is outdoors in a colder climate, you may find success with a cold-water species such as trout. (See more examples in the chart below.) Fish species that are well-matched to the temperature of their tank will grow and reproduce, while fish that are outside the range of their preferred temperature experience stress that will halt their growth, and could lead to death. Though it is possible to adjust the temperature of your tank with a heater or chiller, you can minimize your expenses by choosing a fish species that does not require manipulation of the ambient temperature. Some growers in temperate climates vary their fish depending on the season--swapping out a warm-water fish in the spring and summer for a cold-water fish in the fall and winter.

The choice is clear...or cloudy?

In addition to water temperature, there are other water quality parameters to consider when choosing the fish for your tank. Factors such as turbidity, pH, and dissolved oxygen also play a role in the success of your fish-rearing. It is often best to consider the type of water environment each fish prefers in the wild, and then extrapolate that information to your aquaponic system. Tilapia and catfish originate from ponds, lakes, and marshlands, so they can tolerate lower levels of dissolved oxygen and overall water quality. Trout, on the other hand, come from clear, highly oxygenated streams, which means they will do better in a tank with these characteristics. These species' preferences will factor into choices you make about tank size, fish crowding, what plants you want to grow, and how closely you want to monitor and maintain tank conditions.

To eat, or not to eat, that is the question.

One of the biggest considerations you will need to make before selecting your fish is whether you are intending to harvest your fish for consumption, or whether you are keeping your fish for ornamental purposes. Commercial aquaponic farmers raise tilapia, perch, trout, or other edible species to maximize the profit from their farm. Issues such as breeding potential, time to plate size, cost of fish food (carnivore vs. omnivore), and consumer taste preferences will often dictate which species they choose.

Indoor and small backyard operations may find that ornamental fish such as goldfish and koi are preferable to edible varieties for ease of tank management. Schools that wish to raise edible fish for consumption by students should check with their food service director or county or state health department to learn more about the procedures for harvesting them. Most states require use of a harvesting facility that is approved and inspected by the USDA.

Food for thought: a few final things to consider

When making your final selection for the type of fish you want to raise in your aquaponic tank, you should consider where you are going to purchase the fish and what type of food they will need. Picking a species that is native to where you live is recommended if you have an outdoor tank, because the fish will be acclimated to the surroundings and they won't pose a problem if flooding leads to their accidental release in local waterways. You may also be able to obtain native fish fry or fingerlings (juvenile forms) from local hatcheries. If hatcheries aren't an option, pet stores, local hobbyists, and shipments via the internet are reliable sources for obtaining fish for your tank. Keep in mind that your fish will most likely require supplemental food. Carnivores such as trout need a good source of protein, such as a high quality food pellet, insects, or small crustaceans. Freshwater mussels, shrimp, and crustaceans can actually be raised in the tanks with carnivorous fish. Omnivores such as tilapia will still need supplemental food, but they will also be content to nibble on duckweed and other aquatic vegetation.

Whatever fish species you end up selecting for your aquaponic system, you will undoubtedly find yourself troubleshooting unexpected challenges at some point. Fortunately, most fish commonly used in aquaponics are fairly tolerant of the learning process you will go through, and by choosing a fish species that meets your needs and the tank conditions, you are more likely to be successful.

Aquaponics Design Challenge: Student Worksheet

This activity is designed for in-class or at-home use

Before you begin: What is aquaponics?

It's a combination of Aquaculture (raising aquatic organisms) and Hydroponics (growing plants without soil). In an aquaponics system, plants are grown in water that has had fish living in it. The fish create crucial nutrients (ammonia) that are subjected to bacterial colonies in the water which metabolize the ammonia, ultimately turning it into nitrate the plants can use. Then the plants absorb the nitrate and the clean water is returned to the fish. See our resources on the nitrogen cycle for additional information on this process.

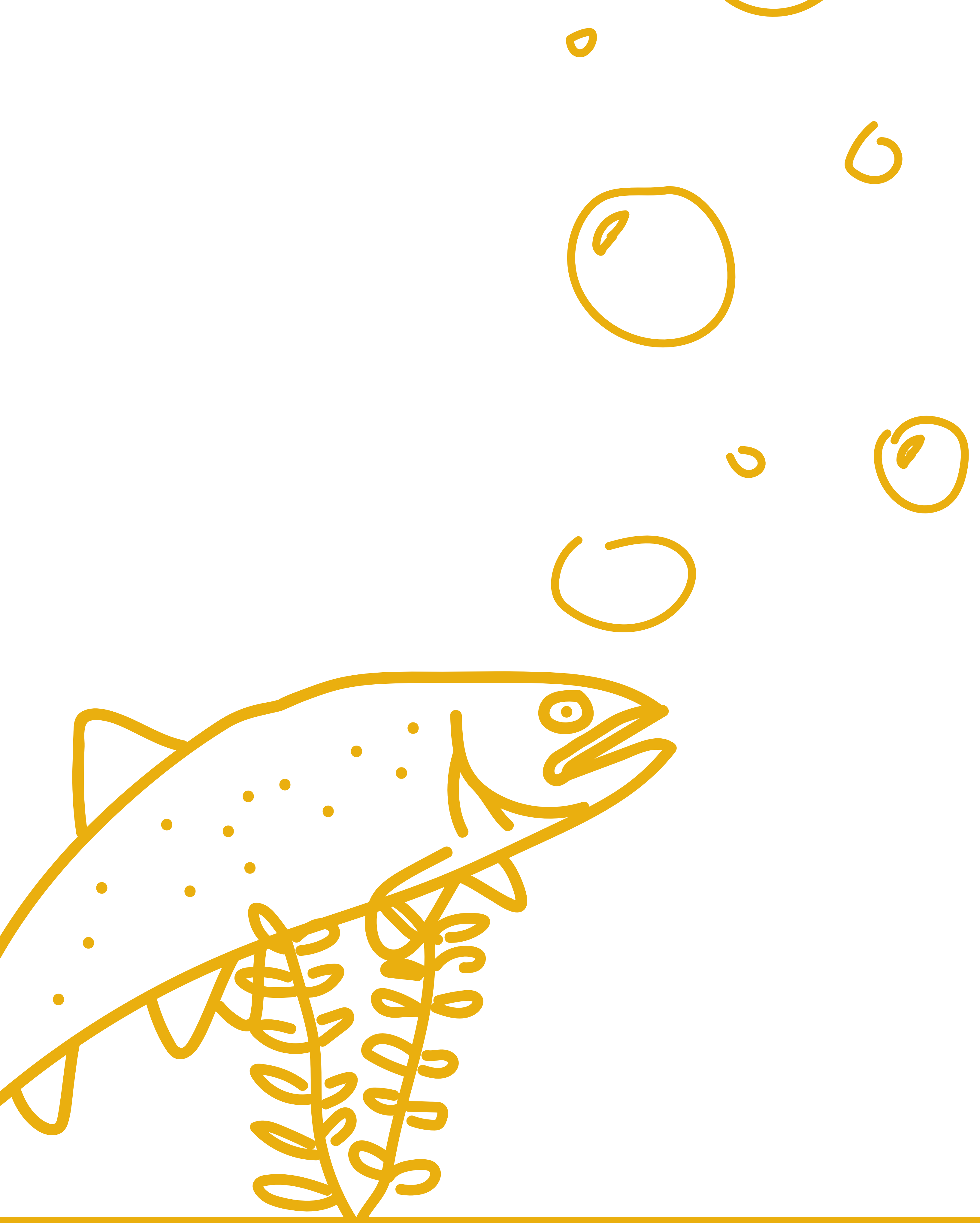
Guiding Questions:

As we consider how to feed a growing population of humans with increasingly limited land and water resources available to us, we need to consider more sustainable alternative options for creating food while minimizing waste. Additionally, we need to find a way to produce food year-round for people with limited access to food or farmable land.

• How can we make the most food using the fewest resources (water, soil, etc.)?
• How can we grow produce (fruits and veggies) and protein (animals) at the same time?
Before You Build: Research & System Considerations
1. What criteria could we use to decide how successful and efficient the system is?
2. Where is your system going to be built?
a. What conditions will it require? (electricity? water source? Natural or artificial light? Etc.)
i. If you are using grow lights, what will you use?
ii. Does your system need special water? 1.
3. Taking into account what you learned about fish from earlier lessons, what type of fish will you use in the system? Consider what you will do with the fish as they grow and which species produce appropriate amounts of ammonia, etc.
a. Once you decide your fish type, what conditions (examples: pH, salinity, etc.) do they require?
b. What do they eat?
c. What temperature do they prefer the water?
d. Do you need to add oxygen to your system?
4. What type of plants are you going to grow in your system? Are you going to have the plants be grown in a hydroponic setup or will they be in pots with drip irrigation of the "fish water"?
a. If it's hydroponic: what will you be planting them in so they won't be fully submerged in water? Also will the fish have access to the roots? Is this something you want?
b. If it's drip: What type of substrate will you plant your seeds in? Consider that you don't want to clog or contaminate your system.
5. What sort of bacteria do you want in your system? How will you get them?
6. Are there other nutrients that your plants will need? How will you provide them?
7. How do you plan to control for pests?

System Design Criteria & Constraints:

Criteria (what your design needs to do):
• Must be able to deliver all resources necessary for fish and plant growth, including light, water, and water cycling functions.
• Must be well constructed
• Must have a detailed blueprint with key parts, materials, water pathways, and dimensions labeled.
DESIGN RESEARCH: Planning is an essential part of any successful engineering design challenge. Planning requires that you consider the structure and function of your product. Think about how your aquaponics system will work and what materials you will use to achieve the desired functionality. Now that you have thought about the key components and requirements of your system, it's time to design it.
Take notes about how you will design your system, what materials you will use, and how you will power your system (pumps, lights, etc.). Notes may be in list (bullet) format and should include sketches. Sketches can be of basic design options or specific aspects (just a part of a design) that you like.



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