

## Unit 2: Water Garden

### OVERVIEW

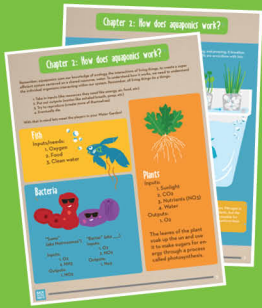
Back to the Roots is on a mission to Undo Food™ and reconnect kids to where food comes from. We're bringing this mission into your classroom with the Garden Toolkit—including the Mushroom Farm, Water Garden, and Garden-in-a-Can—designed to inspire you to take a closer look at how food grows.

Unit 2 is based on the Water Garden that you will use to grow organic wheatgrass and radish sprouts right out of the top of your fish tank! By the end of this unit, you will be able to answer the questions below and be well on your way to becoming an aquaponic expert!



### Chapter 1: What is aquaponics?

Overview of aquaponics and history of agriculture from Mesopotamia to chinampas, rice paddies, and types of aquaponic systems today.



### Chapter 2: How does aquaponics work?

A look at the science inside aquaponics including a chemistry crash course and step-by-step walk through of the aquaponic cycle.



### Chapter 3: Why is aquaponics awesome?

Discussion of the benefits of aquaponics from water usage to plant growth and the global impact of traditional farming.

### WORD BANK

Keep an eye out for vocabulary words in **blue** throughout each chapter, and visit the glossary at the end of the unit to find each definition.

- |             |             |
|-------------|-------------|
| aquaculture | Mesopotamia |
| hydroponics | fertile     |
| ecology     | chinampas   |
| inputs      | apoxic      |
| outputs     | nitrite     |
| agriculture | nitrate     |
| irrigation  | oxygen      |
| pesticides  | fertilizers |

### ACTIVITIES



Water Garden Growth Log



Thinking Cap: Unit Review





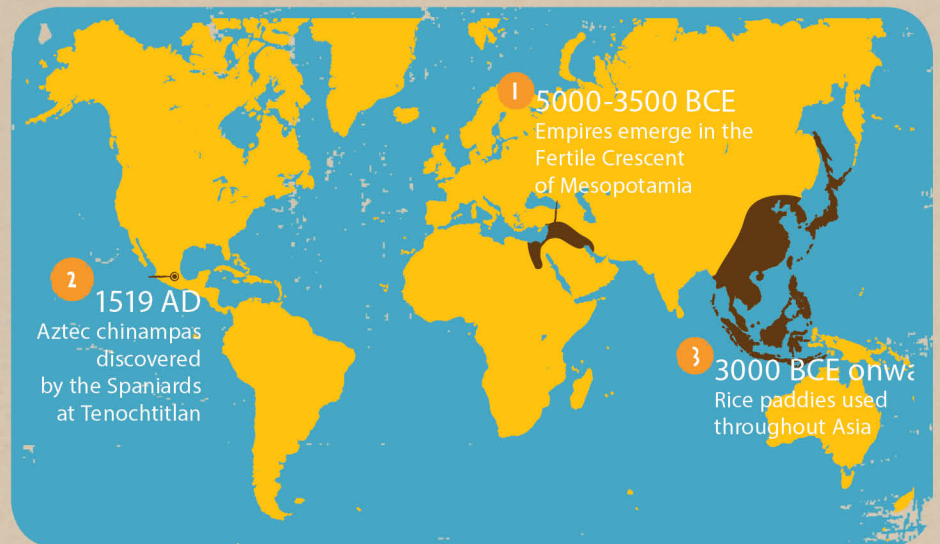
# Chapter 1: What is aquaponics?

Aquaponics is the combination of **aquaculture**, or fish farming, and **hydroponics**, or growing plants in nutrient-rich water. It is a method of growing plants and fish together in a closed system so that the fish “feed” the plants, and the plants “clean” the water for the fish. It draws on our understanding of the needs of living things and how they interact within an ecosystem (Do you remember what an ecosystem is from Unit 1: Mushroom Farm?)

Through **ecology** (the study of ecosystems and their interactions), we see that every living thing performs a function. They all have **inputs**, or resources they need to do what they do, and **outputs**, or wastes they produce. Aquaponics is one of the most efficient ways to grow food because it uses the outputs of fish to provide inputs for the plants, and the plants to perform a needed function for the fish, centered around a shared resource for both—water!

## Origins

People have long understood that water was the key to growing food, and they learned over time that pairing fish with plants would yield great crops. This has been seen throughout history in a number of different kinds of **agriculture**, or food production. It is believed that early civilizations were formed to organize efforts for **irrigation**, or watering systems for crops, to streamline food production for many people. Some systems were very simple, and others much more complicated, but all over the world people found ways to control water so they could produce food.



On the map are three different regions, each with different types of agriculture. Let’s take a look at **Mesopotamia**, the region where it is believed some of the first civilizations emerged.

## Mesopotamia

Mesopotamia, also known as “The Fertile Crescent” was the region between and around two great rivers—the Tigris and Euphrates—in what is now Iraq. These rivers picked up minerals as they flowed to the sea and were abundant with fish. When it rained they would often flood, covering the land along their banks with nutrient rich water.



The land became known as **fertile** because their crops would grow really well in the soil after the floods. Over the next 7000 years empires would rise and fall in this region, making huge efforts to control water to produce food.




# Chapter 1: What is aquaponics?

## Chinampas

In the western hemisphere there were great empires as well. One of the greatest empires was that of the Aztecs; they conquered many others and learned to build **chinampas** to produce food.

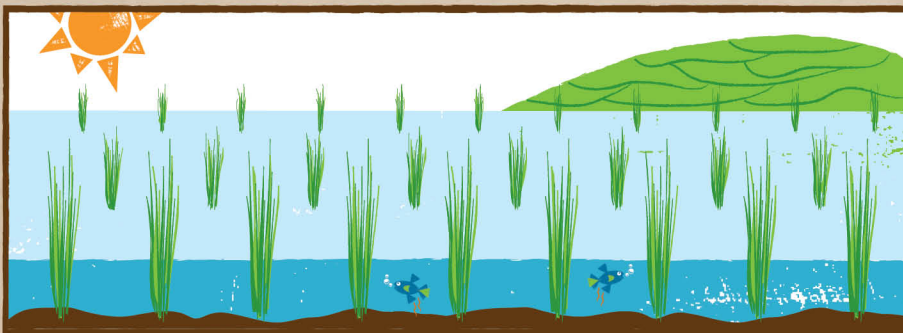
They crafted rectangular plots in shallow waters of lakes by staking out the four corners and wrapping a net around the stakes. Then they would dump in soil, dead trees and branches, and the muck from the bottom of lakes to fill the middle. They planted willow trees on the corners to hold these islands together, cut irrigation ditches across them, and planted their crops in this nutrient rich soil.

They arranged these squares with systems of canals going between them to allow for access by canoe. They would use canoes to row between the islands to plant and harvest, and dive down to add more dirt from the bottom.  **What do you think made the soil at the bottom of the lake so nutrient rich?**

On an island on lake Texcoco (present day Mexico City) was a great city state called Tenochtitlan and there are still remnants of the great city and people today farming the chinampas you can visit!

## Rice Paddy Fields

In ancient China sometime around 3000 BCE it is believed the first rice paddy fields were planted. The same concept powers this ancient food production method—control the water, grow the plants, feed the people.



The rice paddies are flooded and fish swim in. The planted rice is **fertilized**, or nourished, by the fish waste which helps the rice grow.

Sometimes when the farmers drain the rice field they catch the fish on the way out too!

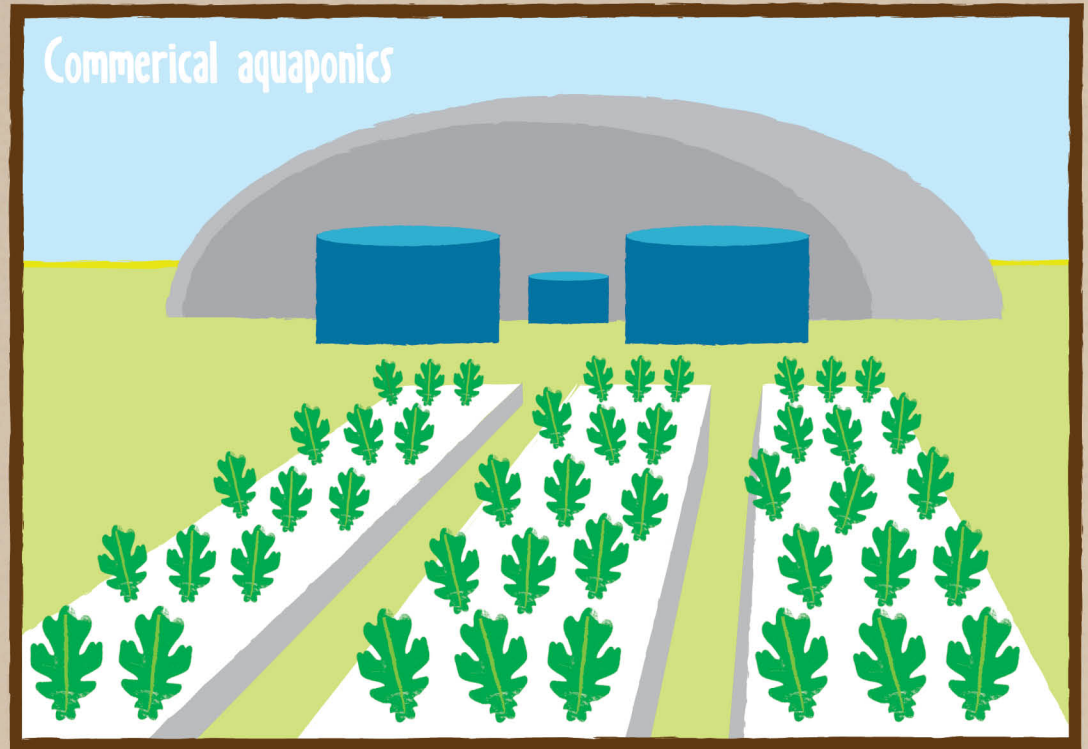
These old types of food production were so successful because they provided the water to the plants. In aquaponics, plants are given all the water they need and a boost of nitrogen—an essential nutrient that plants need in order to thrive.



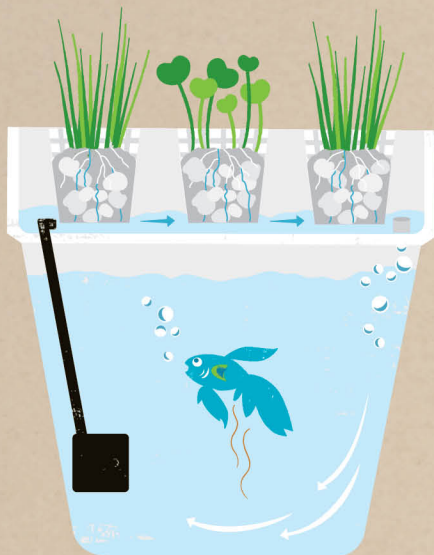
# Chapter 1: What is aquaponics?

## Types of Systems

There are many types of aquaponics systems, because there are many different kinds of hydroponic growing. Each one is a little different but the idea is always the same—get the plants the nutrients they need from the water. Commercial aquaponic systems are designed to grow lots of fish and plants all year long, and they can yield enough to feed whole neighborhoods, or even cities! They use gravity to move most of the water through the system, to be extra efficient and save energy (more on this in Chapter 2!).



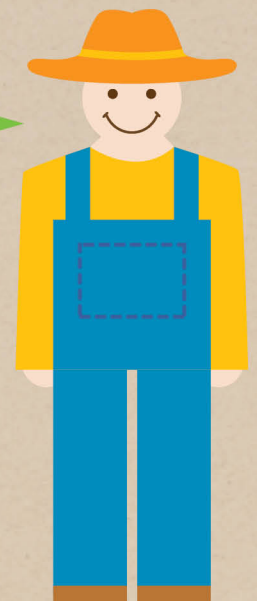
Your classroom Water Garden works using the **nutrient film technique**, which runs nutrient-rich water over the roots. e pump water from our fish tank to our grow bed and let the water flow by the roots to be absorbed. The water then falls back into the tank for the cycle to continue. Whether you're using a big com-



Home aquaponics

### LEARNING TIP!

There are lots of new concepts in this unit for you to learn—take it slowly and read one chapter at a time. Make sure to take a good look at your Water Garden after each one for reference. For the vocabulary words, try making flash cards for each word from the glossary at the end of the unit. You can even cut out and paste the pictures (or draw your own) on each flash card to help you remember what they mean!





# Chapter 2: How does aquaponics work?

## The science inside

Aquaponics uses our knowledge of ecology, the interactions of living things, to create a super efficient system centered on a shared resource, water. To understand how it works, we need to understand the individual organisms interacting within our system. Remember, all organisms do 4 things:

1. Absorb inputs (the resources they need like energy, air, food, etc.)
2. Excrete outputs (wastes like exhaled breath, poop, etc.)
3. Reproduce to create more of themselves
4. Die

In our system, just like in nature, most of the work of connecting the cycle falls on the bacteria. Bacteria interacts with resources on one of the smallest scales to make them available for larger living things. Certain bacteria help break down food in your stomach and, in a similar way, bacteria make nutrients available for plants in the soil. You can think of them like little chemistry robots—they have inputs, perform a specific function, and then put out waste to be used by other bacteria or another living thing. In aquaponics, we are focused on a class known as **nitrifying bacteria**, or bacteria which make nitrogen available for plants.

## Chemistry crash course

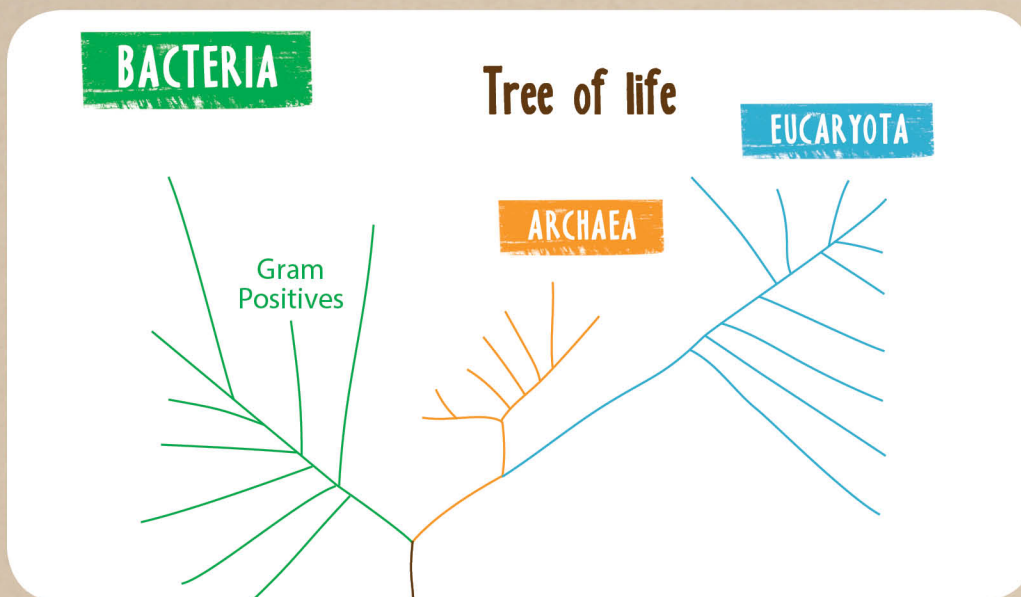
Elements are the building blocks which make up everything in the universe! Living things, or **organisms**, are combinations of elements arranged in a particular structure. Organisms need nutrients to function, which can be absorbed from food. As they function, organisms are constantly using up elements so they can be exchanged and replenish the elements that they need.

One element which is very important to nearly all organisms is nitrogen, which is represented by N in the **Periodic Table of Elements** and in chemical formulas (for example,  $\text{NH}_3$  = **ammonia** from our fish).

There is N all around us, but it needs to be in a useable form for different organisms to absorb it—that's where our nitrifying bacteria come in. They work together to do something called **nitrification**—trans-

forming ammonia ( $\text{NH}_3$ ) into **nitrate** ( $\text{NO}_3$ ); the useable form of nitrogen for plants. 🧠 Can you guess how much of the air around us is made up of nitrogen? (See Fun Fact on page 7 to find out!)

Let's revisit our **tree of life** from Unit 1. This time, let's take a closer look at the bacteria branch. As you can see, the bacterial kingdom is vast, and new organisms are being discovered all the time.



# Chapter 2: How does aquaponics work?

## Fish



### Inputs:

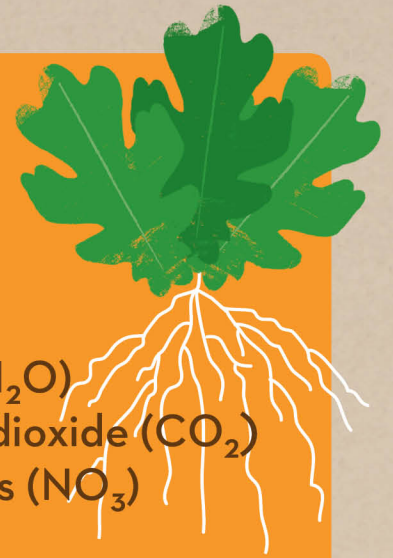
1. Oxygen ( $O_2$ )
2. Water ( $H_2O$ )
3. Food

### Outputs:

1. Poop (high in ammonia,  $NH_3$ )
2. Exhaled breath ( $CO_2$ )

=fuel

## Plants



### Inputs:

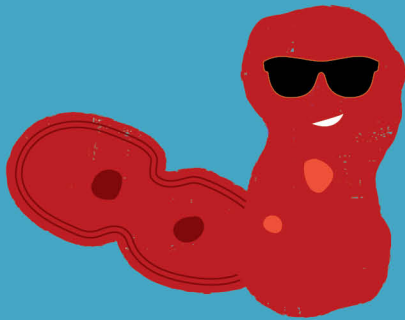
1. Sunlight
2. Water ( $H_2O$ )
3. Carbon dioxide ( $CO_2$ )
4. Nutrients ( $NO_3$ )

### Outputs:

1. Oxygen ( $O_2$ )

=filter

## Bacteria



### "Somo"

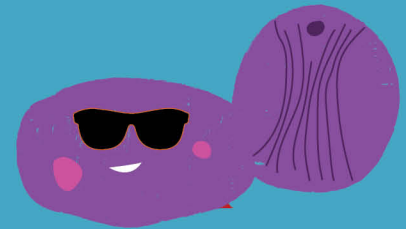
Nickname for Nitrosomonas

### Inputs:

1. Oxygen ( $O_2$ )
2. Ammonia ( $NH_3$ )

### Outputs:

1. Nitrite ( $NO_2$ )



### "Bacter"

Nickname for Nitrobacter

### Inputs:

1. Oxygen ( $O_2$ )
2. Nitrite ( $NO_2$ )

### Outputs:

1. Nitrate ( $NO_3^-$ ) for plants

=engine



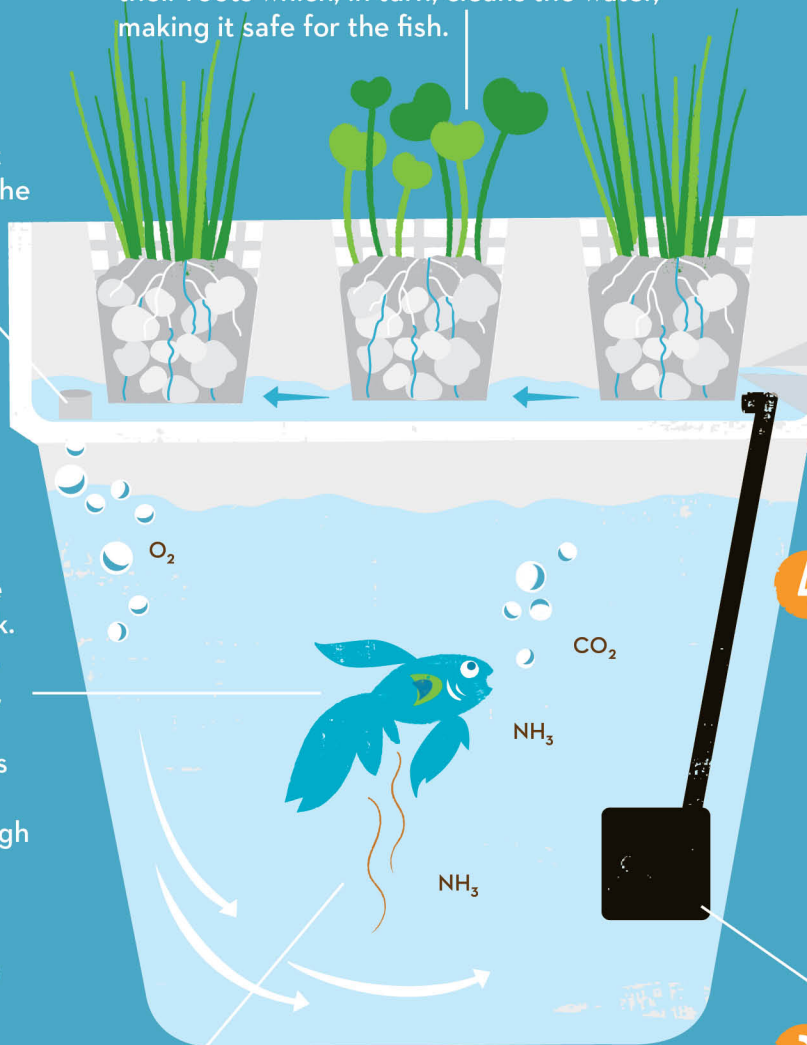
# Chapter 2: How does aquaponics work?

## Swim Through Aquaponics

**7** The clean water falls from the growbed back into the tank, bringing more oxygen from the air as it returns. This allows the fish and bacteria to breathe and the cycle continues!

**6** Nitrate ( $\text{NO}_3^-$ ) is the useable form of nitrogen (N), one of the essential nutrients for plant growth. The plants absorb as much of it as they can out of the water flowing over their roots which, in turn, cleans the water, making it safe for the fish.

**5** Luckily there is our other bacterial buddy, Bacto (or **nitrobacter**, the bacteria that absorbs nitrite) who loves nothing more than to take in as much nitrite ( $\text{NO}_2^-$ ) and oxygen ( $\text{O}_2$ ) as it possibly can to produce nitrate ( $\text{NO}_3^-$ ). Nitrates can also be toxic to fish.



### START HERE:

**1** Take a look at the the betta fish in your tank. It is very busy eating, breathing, swimming, and excreting waste (pooping). It breathes in dissolved oxygen from the water through its gills (they're like lungs for a fish!) and excretes ammonia ( $\text{NH}_3$ ) through its gills and waste.

**2** Any excess waste product becomes toxic if there is enough of it in the environment, but the waste is made up of elements that are needed by other organisms. Over time, the ammonia ( $\text{NH}_3$ ) accumulates and becomes toxic to the fish, but it is exactly what nitrifying bacteria (our friends Somo & Bacter) likes to eat!

**4** Somo (or **nitrosomonas**—the bacteria that absorbs ammonia) uses the ammonia ( $\text{NH}_3$ ) and oxygen ( $\text{O}_2$ ) to produce nitrite ( $\text{NO}_2^-$ ). This is a problem for our fish—nitrite is one of the most toxic substances on Earth for a fish!

**3** The pump takes the ammonia-rich ( $\text{NH}_3$ ) water and brings it up to the grow bed.

**FUN FACT:** "Air" on Earth is 70% nitrogen. Nitrogen is one of the most essential nutrients for plants, but the nitrogen in the air is not in a form that is useable for them. It isn't until our bacterial buddies perform their function that it becomes nitrate).



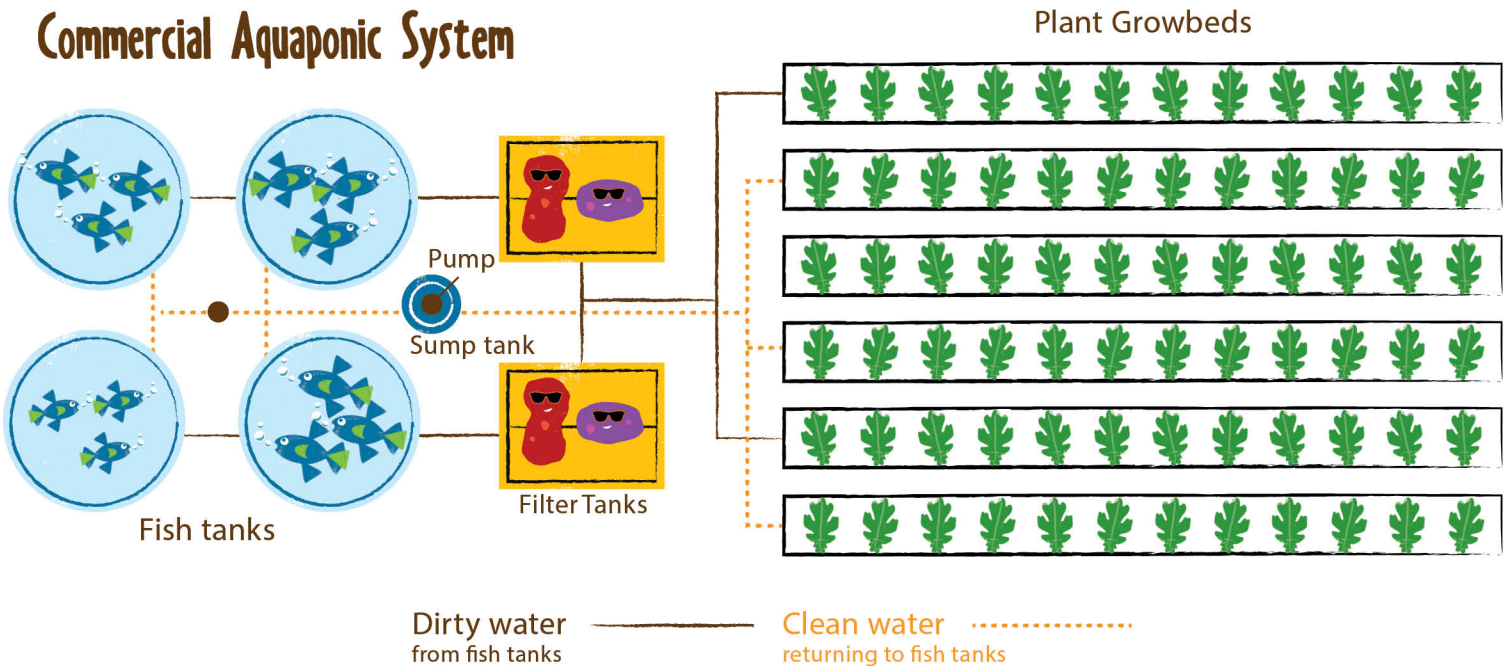
# Chapter 2: How does aquaponics work?

## Commercial Aquaponics

In a commercial system, the four big fish rearing tanks are at the highest point, and they separate fish of different ages, so the bigger fish don't eat the little guys.

The "dirty" water (full of fish waste) flows out into filter tanks which trap the solids and house the nitrifying bacteria (Somo & Bacter!) who turn the ammonia into nitrates.


## Commercial Aquaponic System



The water then flows out to long hydroponic grow tanks (similar to the growbeds in your Water Garden), which can be hundreds of feet long! Often these are full of floating rafts holding the plants, which pull the nitrates from the water.

The clean water flows down to the lowest point, called a sump tank which holds the cleanest water in the system. From here, the water is pumped back to the fish tanks and the cycle continues!

The fish are harvested when they grow big enough to eat, while the plants are harvested weekly to be sold to restaurants, farmers markets, and grocery stores.

 **Compare and contrast your classroom Water Garden and a commercial aquaponic system. How are they similar and how are they different? What are the benefits of each?**

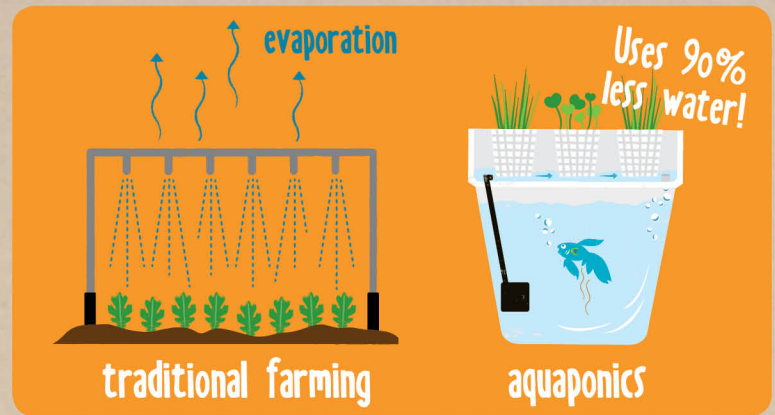


**FUN FACT:** One of the largest commercial aquaponic systems is in the United Arab Emirates. It produces 60,000 heads of lettuce each month and 20,000 pounds of fish each year!



# Chapter 3: Why is aquaponics awesome?

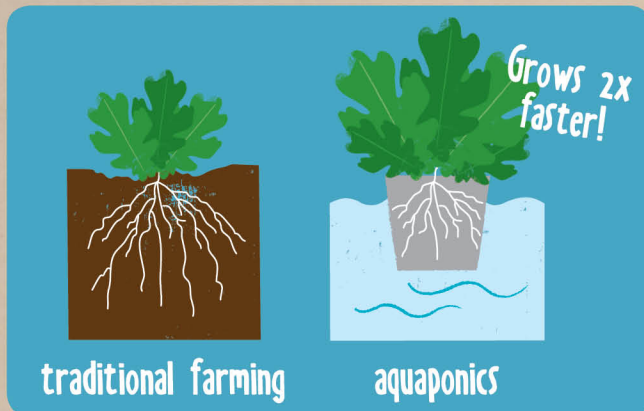
**1 Water savings** From Chapters 1 and 2, we've learned that irrigation is the key to agriculture. In traditional agriculture, many farmers use large sprinklers to spray water out over their fields. Some water goes to the crops, but a lot is lost to **evaporation**—the process of liquid water turning into a gas (test it out for yourself in the Activities section!). The higher the temperature the faster water evaporates, so this is especially bad in hot weather. Water is also absorbed into the soil and lost through **runoff** coming from the field.



In aquaponics, the water moves from the fish tanks through pipes to the growbeds holding the plants. There is no water lost to runoff or soil absorption, and in many systems there is less loss from evaporation!

## 2 Efficient plant growth

Plants use energy to grow what they need to survive. Each part of the plant has its role. Roots grow to seek out nutrients and water from the soil, whereas leaves absorb sunlight for energy, and fruit holds the seeds to reproduce. When the roots don't have to work hard to find what they need, more energy is available to grow leaves and fruit. Plants in aquaponics can grow more than twice as fast, and often much larger because the roots given all the water and nitrogen they need!



## 3 Beyond organic

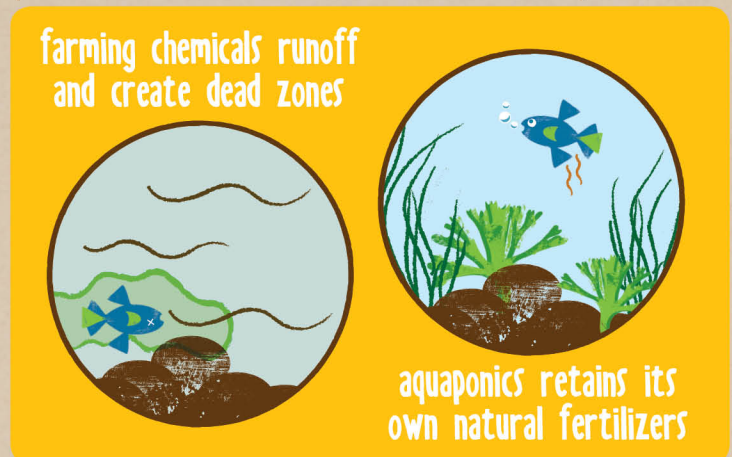
Aquaponic systems work because of their living components; therefore, aquaponic growers are held to a life standard beyond organic standards. In organic farming, there are approved **pesticides**, **herbicides**, and **fertilizers** that are used for killing pests, weeds, and promoting growth. In aquaponics, you cannot use the same chemicals because they would kill the fish and bacteria. The same is true for commercial aquaculture—the antibiotics that are commonly used to fight fish diseases cannot be used in aquaponic systems because they would kill the nitrifying bacteria.

Aquaponics creates and uses its own natural fertilizer (fish waste), and keeps it contained within the system. When farmers spray their fields with fertilizers those nutrients often seep into the groundwater and runoff into streams, rivers, and eventually into the ocean.

When the fertilizers reach these bodies of water, they are consumed by plants—especially **algae**—a simple water plant—causing **algal blooms**, or the rapid growth of lots of algae. Bacteria loves to eat this algae, which depletes much of the oxygen in the water. There are areas where the algal blooms are so huge that the bacteria eating them use up all of the oxygen, leaving the water **apoxic**, or without oxygen. Fish are not able to survive in these areas, creating what scientists call “**dead zones**.” This is an increasing problem in the world's oceans today, emphasizing the need for more sustainable farming methods like aquaponics!



How many dead zones do you think there are in the world? How might you be able to help?





# Vocabulary

**Agriculture** (ag-ri-kuhl-cher) Food production

**Alage** (al-guhl) A simple water plant that grows very quickly

**Algal blooms** (al-guhl blooms) A simple water plant that grows very quickly

**Ammonia** (uh-mohn-yuh) A chemical compound made up of nitrogen and hydrogen (NH<sub>3</sub>)

**Apoxic** (eh-pohx-ik) Without oxygen

**Aquaculture** (ak-wuh-kuhl-cher) Fish farming the study of ecosystems and their interactions

**Chinampas** (chi-nam-puhs) Rectangular plots in shallow waters of lakes to grow crops

**Dead Zones** (ded zohn) An area of water that does not have enough oxygen for life to survive

**Ecology** (ih-kol-uh-jee) The study of ecosystems and their interactions

**Evaporation** (ih-vap-uh-rey-shuhn) The process of liquid turning into a gas

**Fertile** (fur-tl) Capable of producing life

**Fertilizers** (fur-tl-ahy-zer) A substance that increases plant growth

**Herbicides** (hur-buh-sayhd) A substance used to kill plants (specifically weeds)

**Hydroponics** (hahy-druh-pon-iks) Growing plants in nutrient-rich water

**Inputs** (in-poots) The resources a living thing needs in order to perform a function



# Vocabulary

**Irrigation** (ir-i-gey-shuhn) Water systems for crops

**Mesopotamia** (mes-uh-puh-tey-mee-uh) The region where it is believed some of the first civilizations emerged, also known as the “Fertile Crescent”

**Nitrate** (nahy-treyt) The useable form of nitrogen for plants ( $\text{NO}_3^-$ )

**Nitrification** Transforming ammonia ( $\text{NH}_3$ ) into nitrate ( $\text{NO}_3^-$ ); the useable form of nitrogen for plants

**Nitrite** (nahy-traht) A form of nitrogen that is toxic to fish ( $\text{NO}_2^-$ )

**Nitrobacter** (nahy-truh-bak-ter) A bacteria that absorbs ammonia

**Nitrogen** (nahy-truh-juhn) A chemical element needed by all living things

**Nitrosomonas** (nahy-truh-suh-mohn-us) A bacteria that absorbs ammonia

**Nutrient film technique** (noo-tree-uhnt film tek-neek) A growing technique that runs nutrient-rich water over roots

**Outputs** (out-poot) Waste that a living thing produces

**Organism** (awr-guh-niz-uh m) Living things; a form of life

**Periodic Table of Elements** (pe-ri-od-ic ta-ble of el-e-ments) The system used to organize and chart the 118 chemical elements

**Pesticides** (pes-tuh-sahyd) A chemical used to kill plants or pests

**Runoff** (ruhn-awf) Water flowing from the fields