STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

WELCOME TO STEAM FORWARD!

Be Water Wise

Career: Engineer
Episode: Life Support Systems

Even though the habitats at Georgia Aquarium hold 10 million gallons of water, the facility itself uses only as much water as an average supermarket!

Ready for more learning surprises? You are about to meet the Life Support Systems team from Georgia Aquarium and watch STEAM learning at work. To begin, you will view a video hosted by marine biologist Dr. Mike Heithaus. He will show you the three different types of filtration systems (mechanical, chemical, and biological) that process more than 90 billion gallons of water a year at Georgia Aquarium.

After observing how 160 sand filters, 75 protein skimmers and 30 ozone contact towers work together to support over 100,000 animals each day, you will gain a better understanding of the flow of energy and matter in natural ecosystems.

Following the video lead of Life Support Systems Manager, John Masson, you will choose an exhibit type and design your own aquatic habitat and filtration system!

OBJECTIVES: Why am I learning this?

At the completion of this mini-unit, you will be able to:

- Explain how water filtration occurs in natural aquatic environments.
- Describe the importance and function of life support systems used by Georgia Aquarium.
- Compare and contrast how water filtration occurs in natural aquatic environments and man-made aquatic environments like the Ocean Voyager gallery at Georgia Aquarium.
- Define mechanical, chemical and biological filtration.
- Evaluate the effectiveness of mechanical, chemical and biological filters using mathematical data.
- Implement the design process to construct an aquarium habitat.

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name Class Date

Activity 1 – Go with the Flow: Energy and Matter in Ecosystems

Video segment: 00:00–02:20

OBJECTIVES: Why am I learning this?

At the end of this lesson, you will be able to:

- Explain how water filtration occurs in natural aquatic environments.
- Describe the importance and function of life support systems used by Georgia Aquarium.
- Compare and contrast how water filtration occurs in natural aquatic environments verses man-made aquatic environments like Ocean Voyager.

Introduction

Before you are ready to design your own habitat for ocean creatures you need to start, as any good STEAM expert does, with critical background research. First, you will explore the flow of energy and matter in ecosystems. Then, you will compare and contrast how water filtration occurs in a natural environment versus one that is found in a man-made environment such as the Ocean Voyager habitat at Georgia Aquarium.

1. Using your knowledge and background research, **draw a diagram** of the flow of **energy**, **phosphorus**, and **waste products** in an *open ocean ecosystem* that includes whale sharks and dolphins (Don't forget the **phytoplankton**!). Be sure to include what happens to organisms that die without being eaten and to the waste products of those organisms.

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name____Class____________________Date________________________

2. **Describe** what happens to **waste products** and **phosphorus** in the *open ocean*.

____

____

____

____

3. **Draw a diagram** of the flow of **energy**, **phosphorus** and **waste products** in *Georgia Aquarium's Ocean Voyager habitat*. Be sure to include what happens to organisms that die without being eaten and to the waste products of those organisms.

4. In the video segment, Dr. Heithaus explains the ways that nature takes care of waste in an ecosystem, including filter feeders, decomposers, and wetlands. How does the flow of energy, phosphorus and waste **differ** between the *natural oceans* and the *Ocean Voyager habitat*?

____

____

____

____

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name ______________________________ Class ______________ Date ______________

Activity 2 – Filter It Out!

Video segment: 02:20–05:27

OBJECTIVES: Why am I learning this?

At the end of this lesson, you will be able to

- Define mechanical, chemical and biological filtration.
- Evaluate the effectiveness of mechanical, chemical and biological filters using mathematical data.

Introduction

Now that you have learned about the flow of energy and matter in ecosystems and the importance of filtration systems in both natural and man-made environments, you need to understand how three different types of filtration work. This activity dives into chemical, mechanical and biological filtration and walks you through the mathematical calculations for how these systems work.

Sand Filter: Mechanical Filtration

Sand filters physically trap solid wastes as water flows through the filter. In the video, you see Dr. Heithaus help clean out one of the 160 sand filters at Georgia Aquarium. This is an example of mechanical filtration.

1. Using the table below, **calculate** the amount of water filtered per day at five different flow rates.

Table 2.1. The effectiveness of sand filters at removing large waste particles.

Flow Rate (gallons per minute per square foot of filter)	Proportion of large particles removed	Amount of water filtered per day (gallons)
4	97	
8	96	
12	95	
16	60	
20	20	

Name ______________________________ Class ______________ Date ______________

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

2. Use the data in the table on the previous page to make a **graph** of the proportion of large particulate matter removed from the water. Be sure to label both axes! Title your graph: *Figure 2.1. Influence of flow rate on the proportion of waste removed by a sand filter.*

3. If you are trying to optimize the amount of large particles of solid waste from the water, but not buy too many filters, which flow rate should you use? **Support your answer** using your graph and the calculations you made in your table.

____

____

Deeper Dive*: Why do you think water filtration is less efficient when the water flow is faster?*

4. The sand filters you are going to use for your aquarium design challenge have a surface area of 60 square feet. What is the optimal amount of water filtered per minute for a filter this size? **Show your work**.

____

____

Deeper Dive*: Calculate how much water would be filtered per minute for filters of different sizes.*

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name ______________________________ Class __________ Date __________

Protein Skimmer: Chemical Filtration

Protein skimmers use chemical filtration to draw out small compounds from the water (that would not be captured in a sand filter) and force them onto surface bubbles. These bubbles form foam that can be collected. Some of the compounds that are collected include proteins, amino acids, fats/oils, bacteria, carbohydrates, metals, salts and waste products/detritus. The protein skimmer works by injecting the right amount of air into the water flowing through it.

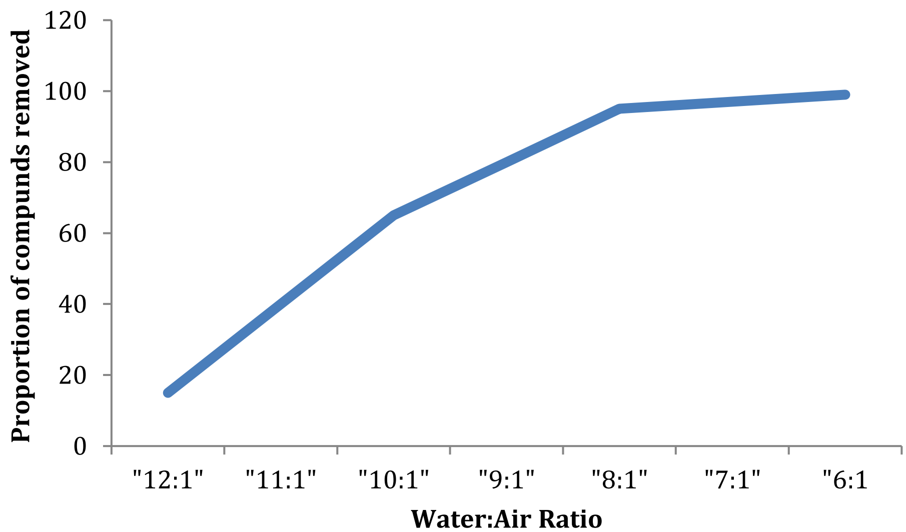


Figure 2.2. Proportion of compounds removed from water passing through a protein skimmer at different water to air ratios.

5. Based on the data in Figure 2.2, what is the best water to air ratio for protein skimmers? Consider that it takes both money and energy to inject air into the water!

____

____

6. If you have a protein skimmer with 800 gallons of water passing through it every minute, how much air needs to be injected each minute for it to work efficiently?

____

____

GEORGIA AQUARIUM

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name ______________________________ Class ______________ Date ______________

Ozone Contact Tower: Chemical Filtration

Ozone contact towers inject ozone gas (O_3) into the water. This gas is very reactive and chemically breaks down organic compounds like harmful pathogens and waste products that can then be more easily removed with additional filtration. The key to ozone doing its job is how long it is in contact with pathogens or waste products. The chemical Chlorine is another disinfectant often used to clean water. Which method is faster?

Table 2.3. Time required to achieve a 99.9% disinfection rate.

Disinfectant type	Time (hours)
Ozone	3.3 hrs.
Chlorine	20 hrs.

7. Use the table above to create a **graph** of the time required to disinfect water.

8. Which disinfectant would be best at Georgia Aquarium? Why?

____

____

____

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

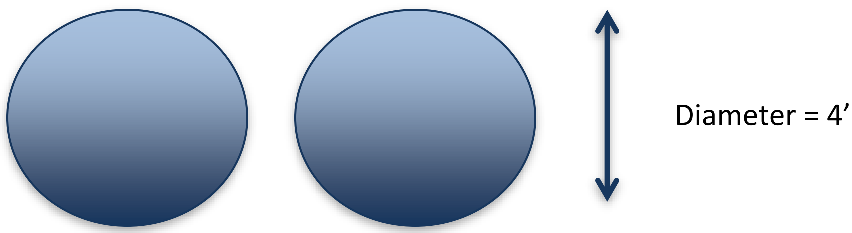
Name ________________________ Class __________ Date __________

Deaeration Tower: Biological Filtration

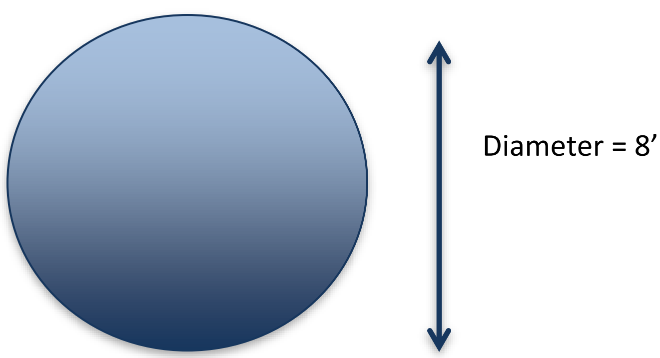
Deaeration towers remove gasses from the water and use biological filtration before sending water back to the exhibit. Water flows through beneficial bacteria that convert ammonia (NH_3) which is toxic to fish into non-toxic nitrate. This process is critical for keeping the water clear and the water quality high. Figuring out how much water to move through deaeration towers is like sand filters. The best rate is 15 gallons per minute per square foot of filter.

9. **Calculate** the amount of water that the two deaeration tower setups (shown below) can filter each day. Remember, the area of a circle is pi x r^2. Calculate the area of circles to the nearest square foot.

A)



B)



Name ________________________ Class __________ Date __________

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

10. Which sized diameter filter is best, assuming it fits the space you are designing?

____

____

Deeper Dive*: Explore how the area of a circle scales with its diameter or radius. With that in mind, is it better to buy two 8” pizzas or one 16” pizza? (You’re really hungry!)*

N*ame* ____________________ *Class* __________ *Date* __________

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Activity 3 – Make it Work in Your Own Exhibit!

Video Segment: *05:30-07:44*

OBJECTIVES: Why am I learning this?

At the end of this design challenge, you will be able to

- Implement the design process to construct a habitat.
- Evaluate the effectiveness of their own habitat and that of their peers and incorporate feedback to iterate and improve effectiveness.

Introduction:

Now it's time for you to design your own aquarium exhibits based on what you have learned! You can take this challenge further by testing actual filtration systems, just like the architects, designers, engineers, technicians, and construction workers do in the video. It is recommended that you draw a conceptual sketch of your habitat before you complete the quantitative activities in order to determine your filtration needs.

STEP 1: Choose your exhibit. You can build a coral reef, create an open-ocean habitat, develop a kelp forest, or establish a sea turtle pool for injured turtles. **Circle or highlight the exhibit selected and use this information for the remainder of your design project**.

Deeper Dive*:* Complete the following steps for all four of the exhibit types!

Table 3.1. Aquatic life living in each exhibit

Exhibit type	**Aquatic life living in your exhibit**
Coral Reef	1 reef, 500 small fish, 100 medium fish, 500 large fish, 100 snails
Open Ocean	2 whale sharks, 5 manta rays, 50 jacks, 1000 small fish
Kelp Forest	40 kelp stalks, 20 garibaldi, 10 rockfish, 2 wolf eels, 2 octopus
Sea Turtle Pool	10 sea turtles, 500 small fish, 1 oyster bed

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name ____________________________ Class ____________ Date ____________

STEP 2: How much water is there in your exhibit?

1. Complete the table below to get your exhibit filled. *Hint: 1 cubic foot of water is about 7.48 gallons.*

Table 3.2. Sizes of each exhibit

	Width (feet)	Length (feet)	Depth (feet)	Cubic feet	Gallons
Coral Reef	25	40	20		
Open Ocean	75	300	30		
Kelp Forest	25	30	30		
Sea Turtle Pool	40	50	15		

STEP 3: How many filters will you need?

2. Complete the corresponding table to design your filtration system. **Each student or team must fill in the missing data for the table corresponding to the exhibit or exhibits you are proposing.**

- *Hint 1: To calculate the minimum number of filters of each type for an exhibit, the total amount of water that needs to be filtered in a day (calculated in Table 3.2) should be divided by the per unit rate. The result should be rounded up to the nearest whole number.*
- *Hint 2: Ozone towers need to treat 20% of the total flow through the exhibit.*

*Table 3.3. Minimum needs for my **Coral Reef** exhibit*

Equipment Type	Size (square feet)	Flow rate per unit (gallons per minute)	Minimum # of filters for exhibit	Total gallons per minute
Pumps		**650 gpm**	**4**	
Sand Filters	**20 sq. ft.**			**1,920 gpm**
Protein Skimmers		**340 gpm**		
Deaeration Towers			**1**	
Ozone Contact Towers			**1**	

GEORGIA AQUARIUM

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

Name ______________________________ Class ______________ Date ______________

*Table 3.4. Minimum needs for my **Open Ocean** exhibit*

Equipment Type	Size (square feet)	Flow rate per unit (gallons per minute)	Minimum # of filters for exhibit	Total gallons per minute
Pumps		**2,197 gpm**	**40**	
Sand Filters	**100 sq. ft.**			**66,000 gpm**
Protein Skimmers		**1,094 gpm**		
Deaeration Towers			1	
Ozone Contact Towers			1	

*Table 3.5. Minimum needs for my **Kelp Forest** exhibit*

Equipment Type	Size (square feet)	Flow rate per unit (gallons per minute)	Minimum # of filters for exhibit	Total gallons per minute
Pumps		**584 gpm**	**5**	
Sand Filters	**20 sq. ft.**			**2,160 gpm**
Protein Skimmers		**380 gpm**		
Deaeration Towers			**1**	
Ozone Contact Towers			**1**	

*Table 3.6. Minimum needs for my **Sea Turtle Pool** exhibit*

Equipment Type	Size (square feet)	Flow rate per unit (gallons per minute)	Minimum # of filters for exhibit	Total gallons per minute
Pumps		**2,197 gpm**	**5**	
Sand Filters	**100 sq. ft.**			**8,239 gpm**
Protein Skimmers		**305 gpm**		
Deaeration Towers			**1**	
Ozone Contact Towers			**1**	

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

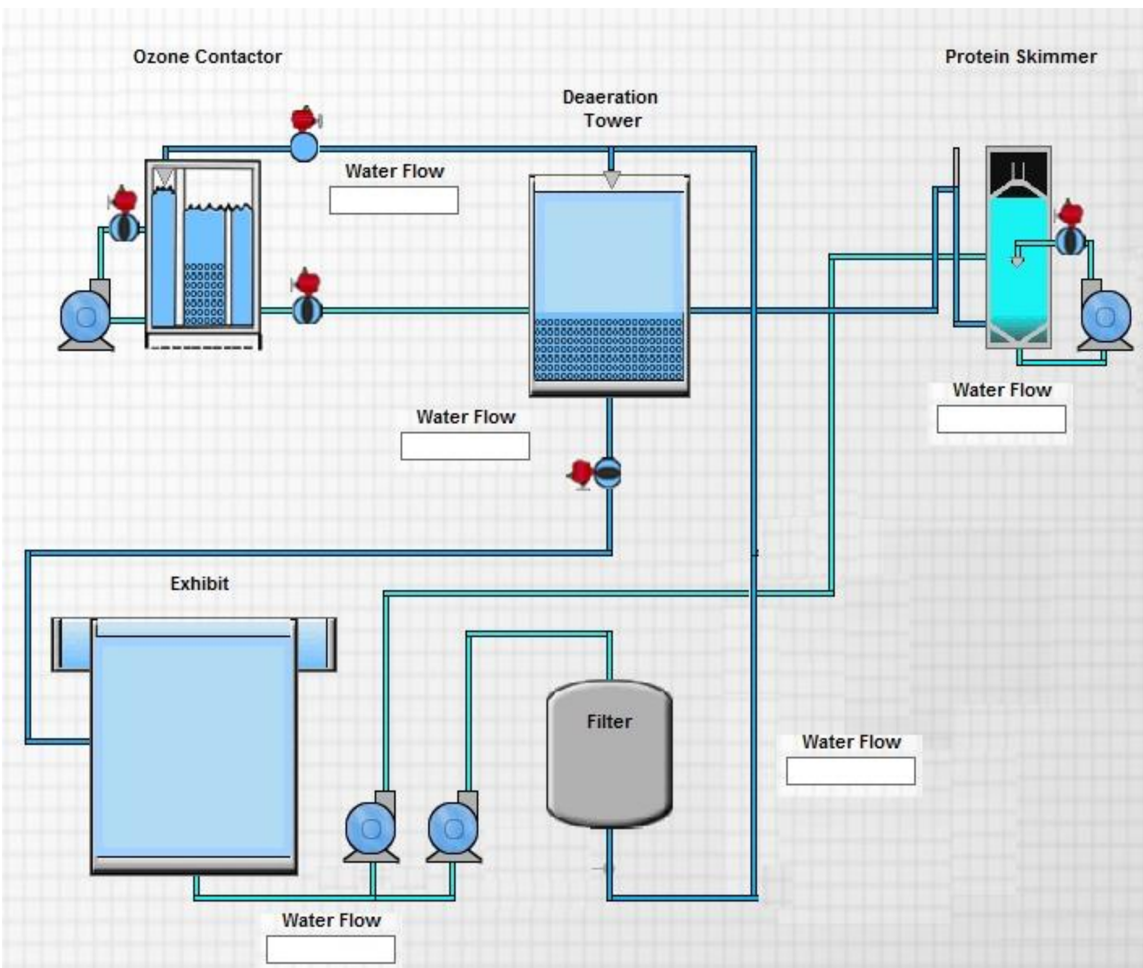
3. How many times per day is all of the water in your exhibit(s) treated? Would you use the minimum amount of pumps and filters? Why or why not?

____

____

Step 4: Use the space on the next page to **design your habitat**. You can also access Computer-Aided Design (CAD) software if you prefer. Label all of the components and make sure you have the right numbers for each. Also, your exhibit should be comfortable for guests and easy to maintain for the team behind the scenes. A legend should be included and the habitat drawn to scale.

Refer to the diagram from the video, shown below, to get started:



STEAM FORWARD – EPISODE 5

Life Support Systems [Student Version]

Name ____ Class ________________ Date ____________________

STEAM FORWARD – EPISODE 5
Life Support Systems [Student Version]

In The Field

How can you STEAM FORWARD in your own learning? Get up close and personal with an expert from Georgia Aquarium and learn what kind of background and experience it takes to be a member of the STEAM TEAM!

MEET: JOHN DAVID MASSON
Manager, Life Support Systems
University of Georgia
Major: Geology

What is the most exciting part of your job with Georgia Aquarium? Designing animal life support systems and seeing them turn into reality. It's always a good feeling when you do the math, draw out the design, purchase the equipment, coordinate construction/installation and watch your design grow and work (hopefully).

What advice do you have for students interested in doing what you do? Stay passionate about learning, focus on what you love and what makes you happy. "If you love your work you will never work a day in your life".

What is something surprising or unexpected about your career path? I was going to go into the oil or mining industry, as I always found earth history and geology fascinating. But the hobby I loved that put me through college gave me a career opportunity that I couldn't pass up. Science, Math, Conservation, the Ocean and my interest in animals - all in one.

What do you say to students who ask "Why am I learning this?" To be and get better. It's not enough to glide through life. If you can be better, why not get better? You never know when this will come in handy. After all, no one would have expected a Geologist to be surrounded by fish and piping but here I am!