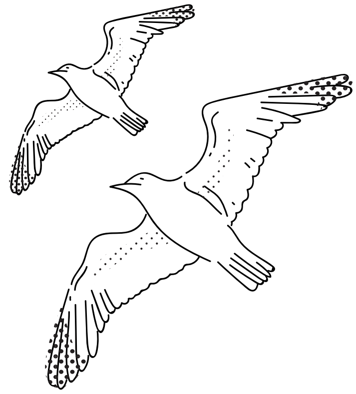

Ecosystem Engineers

How Oysters Help Sustain our Environment

STEM curriculum for teachers grades 4-10 — brought to you by Billion Oyster Project, with support from Con Edison

presented by

BILLION OYSTER PROJECT

conEdison

Billion Oyster Project (BOP) is a nonprofit organization on a mission to restore oyster reefs to New York Harbor through public education initiatives.

Why oysters? Their reefs have the ability to filter water, provide habitat for marine species, and help shield NYC shorelines from storm damage. Founded on the belief that restoration without education is temporary, and observing that learning outcomes improve when students have the opportunity to work on real restoration projects, collaborating with public schools is fundamental to BOP's work. Billion Oyster Project designs STEM curriculum through the lens of oyster restoration for New York City schools, engages New York Harbor students in large-scale restoration projects, collects discarded oyster shells from 75+ NYC restaurants, and engages thousands of volunteers. The project has installed 30 million oysters across 13 reef sites so far.

To learn more, subscribe to BOP's email list at bit.ly/bopnews, and follow @billionoyster on Twitter and Instagram and @billionoysterproject on Facebook.

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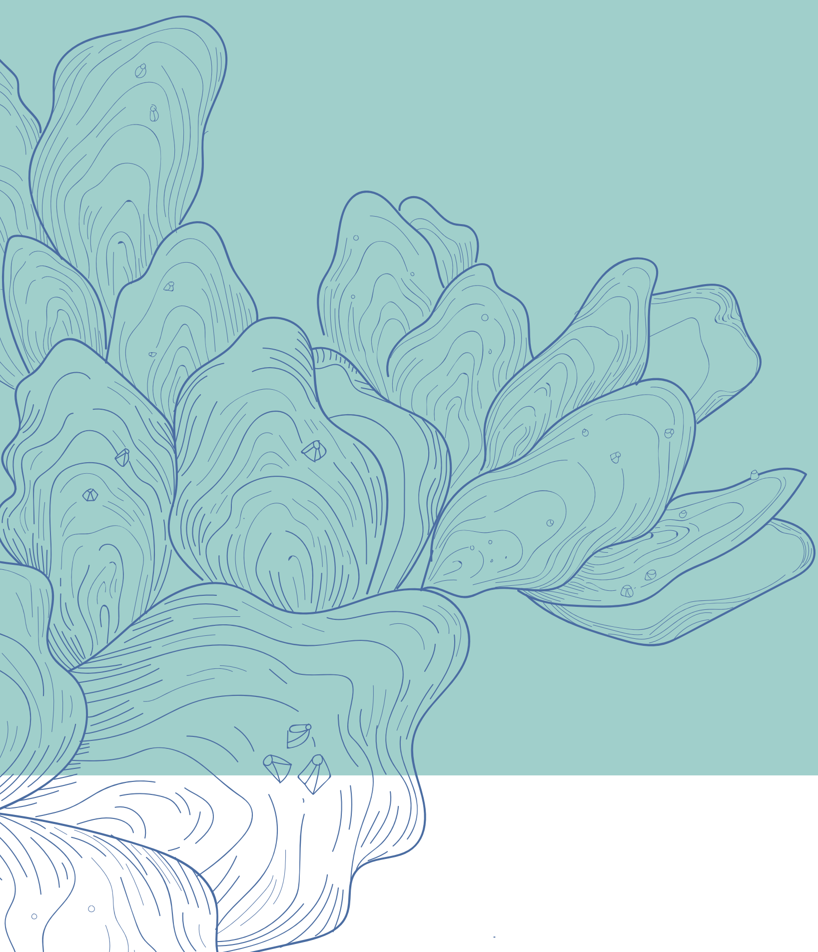
Table of Contents

Lesson One

Oyster Anatomy - What's Really in There?



Lesson Overview

Grade: 4-10
Class Periods: 3

Lesson Summary

Students explore the external and internal anatomy of an oyster through observation, dissection and two different design challenges.

Objective(s)

- Dissect an oyster.
- Observe the structures of oyster's anatomy and make inferences.
- Sketch the oyster's anatomy and accurately label it.
- Identify major body parts and structures of the oyster.
- Design an oyster predator that takes advantage of the oyster's anatomy and morphology.

Materials & Resources

Supplies (for each group)

- 2 live oysters per group (1 closed and 1 shucked oyster)
- Paper plate
- Hand lenses
- Sharpened pencil
- 1 delicate item per group (e.g. crispy cookie, hard boiled egg)
- Household items (e.g. coffee stirrers, paper, cardboard, cream cartons, tissues, cotton balls, string, tape, rubber bands, etc.)

Handouts

- External Oyster Anatomy
- Oyster Design and Engineering Challenge
- Internal Oyster Anatomy
- Oyster Anatomy Diagram

Before You Get Started

Tips for Teachers

- Be sure to understand if any of your students have shellfish allergies. Take any necessary precautions.
- Oyster shells have very sharp edges. Acquire shells that have been worn down a bit or make students aware of this danger to avoid injury.
- If you are able, get a volunteer to come into your class and help you shuck the oysters. If you have to do it yourself be sure to use gloves and practice at home first.
- Give students expectations about their sketches. "It's okay if you don't feel that you are an artist. Labeling will make any sketch understandable."
- Give students expectations about the dissection process. Explain why smushing the oyster's body is not productive, but plan on having an extra shucked oyster or two in case some students do spill or smush it.

Preparation

- Shuck an oyster and check it out yourself before you do this lesson with the class. Students will likely need help finding body parts, and having some familiarity with the anatomy will make the lesson run more smoothly.
- Consider how and when you will shuck the oysters. If possible, shuck the oysters shortly before students arrive in class.
- When shucking, the tissue of the oyster body should be carefully separated from the top, flatter shell and remain attached to the bottom, cupped shell. Set the removed top shell on top of the exposed body.

Instruction Plan

Engage

Students explore a live (closed) oyster and make observations and predictions.

1. Students get into small groups.
2. Each group gets a live oyster. The two shells should be closed tightly.
3. Students touch and carefully observe the oyster.
4. Each student gets an External Oyster Anatomy worksheet and completes it with their group

5. Ask some or all of the following questions to the class as a whole:
   - What is an oyster? (Note: Oysters are mysterious. Some students may think the oyster is more closely related to a rock or an inanimate object.)
   - What does an oyster look like on the outside?
   - What clues does the outside of the oyster give us about the inside?
   - What do you think the oyster looks like on the inside?
   - What body parts do you think it has in there?
   - Does the oyster have eyes, ears, mouth, lungs, heart, brain etc?
   - Which body parts do you think the oyster needs to survive?
   - What function does the shell serve?
   - How might an oyster be eaten by prey?
   - How do you know if the oyster is alive or dead?
6. Record the students' observations and predictions on a class chart for reference later in the lesson.

Explore

Students design and engineer a "shell" to protect a delicate item, mimicking the oyster's exterior anatomy.

1. Walk around the classroom with an open, shucked oyster and allow the students to take a quick look (and a poke) at both shells and the oyster's body inside the shell.
2. Return to the class chart (above) and emphasize the idea that the soft body of the oyster needs to be protected for the oyster to survive.
3. Each group gets some type of delicate item such as a crispy cookie or a hard boiled egg and an Oyster Design and Engineering Challenge worksheet.
4. Explain: The item is delicate and can be easily ruined. (Gulls sometimes eat oysters by holding the oyster in its mouth, flying up a couple dozen feet and dropping the oyster on a rock or other hard surface.)
5. Ask: How might you design a protective covering or structure to keep the item from being ruined?
6. Each group gets a variety of household items (e.g. coffee stirrers, paper, cardboard, milk cartons, tissues, cotton balls, string, tape, rubber bands, etc.).
7. Each group creates a structure that will protect the delicate item if dropped.
8. Students continue to work on the Oyster Design and Engineering Challenge worksheet.
9. Each group tests their structure by dropping it from a designated height. Groups then carefully open the structure to observe and record the results of the drop test.

Explain

Students share their "shell" structure with the whole class and discuss.

1. Students walk around the room to observe each groups' structure and result of their drop test.
2. Groups share their structure and process. They can explain why they chose certain materials to make the structure, how the structure responded to their test and what modifications they would make to the structure and why.
3. Discuss: Patterns among the structures each group built. For example, the structures may have a hard outer layer (e.g. cardboard), a soft inner layer (e.g. cotton balls), and closures (e.g. rubber bands).
4. Ask: How do your structures compare/contrast to an oyster's structure/anatomy?
5. Return to the class chart (above) and review the properties of an oyster shell.
6. Discuss: How does the color, texture and two shells of the oyster help it survive?
    - Shell color (dappled grey) blends in with the bottom of the harbor (camouflage).
    - Rough, bumpy texture on outside of shell gives plants and other animals a place to attach, creating habitat and adding more camouflage.
    - Smooth texture on inside of shell is appropriate for the soft body of the oyster.
    - Hinged shell allows the oyster to open to feed and to close up tight to protect itself.

Extend

Students rework their "shell" based on the result of the first drop test and other groups' structures.

1. Each group tests their structure a second (or third) time by dropping from the same (or possibly a greater) height.
2. Students get an additional copy of the Oyster Design and Engineering Challenge worksheet to record each successive attempt and result.

Elaborate

Students explore the internal anatomy of an oyster.

1. Each group gets a hand lens, a sharpened pencil (to use as a "dissection" tool) and a shucked oyster on a paper plate. Make sure to hand out the shucked oyster with the

removed shell placed on top so the students can open it.
2. Each student gets an Internal Oyster Anatomy worksheet.
3. Groups carefully lift the top shell off their oyster and immediatelymake observations (before the inside of the oyster falls or gets ruined).
4. Students use the sharpened pencil as a dissection tool to carefully explore the oyster's body. For example, lift up the mantle layer to reveal the gills, or follow the edge of the gills up to the palps and mouth.
5. Students work on their Internal Oyster Anatomy worksheet and sketch the body of the oyster.
6. Each student gets an Oyster Anatomy Diagram (with labels) and uses it to label their own sketch.

Evaluate

Students design their own organism that is a predator of the oyster.

1. Students sketch and describe their oyster predator. Students must specifically refer to the oyster's anatomy as they describe how their organism preys on the oyster.
2. What challenges or barriers must the predator overcome in order to prey on the oyster? How will the predator take advantage of the fact that the oyster is sessile (does not move)? What part of the oyster will the predator eat? Why? Does the predator live on or around the oyster reef?

Education Standards

Next Generation Science Standards - Disciplinary Core Ideas

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). (3-5-ETS1-1)

ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution.

Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)

- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

NAME ______________________ DATE ______________________

External Oyster Anatomy

External Observations What do you see, smell, feel, hear? (Let's hold off on tasting.) Make sure you discuss things such as colors, texture, shapes, sizes, live vs. dead oysters, etc. Be specific and FILL UP THIS BOX!	
External Sketch Now that you have taken a close look at your oyster, it's time to sketch it. Make sure you sketch both sides of your oyster. Use shading and labels.	
Side 1	**Side 2**

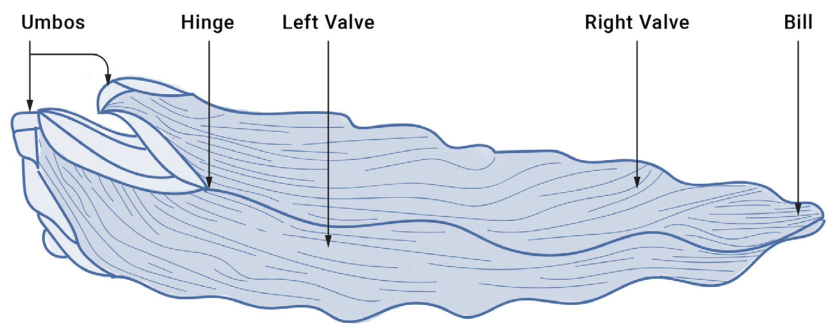
NAME ______________________ DATE ______________________

External Oyster Anatomy

Oyster Shell Diagram

Match your oyster to this diagram. Use this information to help label your own sketch.

Oysters have a narrow end called the **umbo** where the **hinge** is located. Oysters have two shells, called **valves.** Your oyster should have the cupped (left) valve underneath and the flatter (right) valve on top.



Try pulling the two shells apart. Make a prediction: What do you think holds the two oyster shells together?
Do you think your oyster is alive or dead? Explain your answer. What clues does the external anatomy of the oyster give you as to whether it is alive or dead?
Make note of anything your observations leave you wondering about. Don't be shy!

NAME ______________________ DATE ______________________

Internal Oyster Anatomy

Internal - Observations

- What do you feel? See? Smell? (Let's hold off on tasting.)
- Discuss things such as colors, texture, shapes, sizes, etc.
- Describe the body of the oyster. Can you see or feel bones? Is there a head? Do you see blood? Be specific and FILL UP THIS BOX!

Internal - Sketch

Eastern Oysters can be slightly different sizes, shapes and colors. Draw your sketch based on your real oyster (not the Oyster Anatomy Diagram).

Use the diagram to help you label your sketch.

NAME ______________________ **DATE** ______________________

Internal Oyster Anatomy - Taking a Closer Look

Read the below paragraphs out loud with your group and follow along using your pencil to find and point at the appropriate part of the oyster's anatomy.

Look at the two oyster shells **(valves)**. The two shells were joined by a tough and flexible **hinge**. We broke the hinge ligament when we opened your oyster, but you can find its remains near the umbo. We also cut through the strong **adductor muscle**. This muscle keeps the oyster shut. Find the tough adductor in the middle of the softer tissues. The oyster relaxes this muscle to open its shell just a crack to let water flow in and out.

Why do you think the oyster needs to let water flow in and out of its shell? What does this water contain that is necessary for the oyster's survival?

Look at the soft body of the oyster. Feel the inner surface of shell.

Why do you think the oyster makes its shell so smooth on the inside?

NAME ______________________________ **DATE** ______________________

Internal Oyster Anatomy - Taking a Closer Look, Continued

Read the below paragraphs out loud with your group and follow along using your pencil to find and point at the appropriate part of the oyster's anatomy.

Find the feather-like flaps that are the gills. The **gills** allow the oyster to take in dissolved oxygen from the water (similar to how we breathe in oxygen from the air). Look carefully at the gills with the lens. See all the little ridges or ruffles in the gills?

Why do you think this gill design allows the oyster to take in more dissolved oxygen than if the gills were just flat?

The gills also have another very important function: they collect food! The oyster's gills are coated in a sticky mucus, so they can trap microscopic algae from the water. The algae then moves up the edge of the gill toward palps. Find the leaf-like palps, up near the umbo end of the shell. Between the palps is a pinhole mouth (hard to see).

What do you think is the function of these leafy "lips"? (Helpful hint: they aren't for kissing.)

NAME ______________________ DATE ______________________

Oyster Design and Engineering Challenge

List the materials you chose and explain why you chose each material. How did you think each material would help protect the delicate item?

Type of Material	Why did you choose this material?

What materials would like to include in your design that are not available to you today? Explain.

NAME ______________________ DATE ______________________

Oyster Design and Engineering Challenge

Make a prediction about what will happen to the delicate item.

Sketch and label your structure.

NAME ______________________ DATE ______________________

Oyster Design and Engineering Challenge

How did your "shell" responded to the drop test(s)?

What modifications would you make to your structure in order to better protect your item? Explain why you would make each modification.

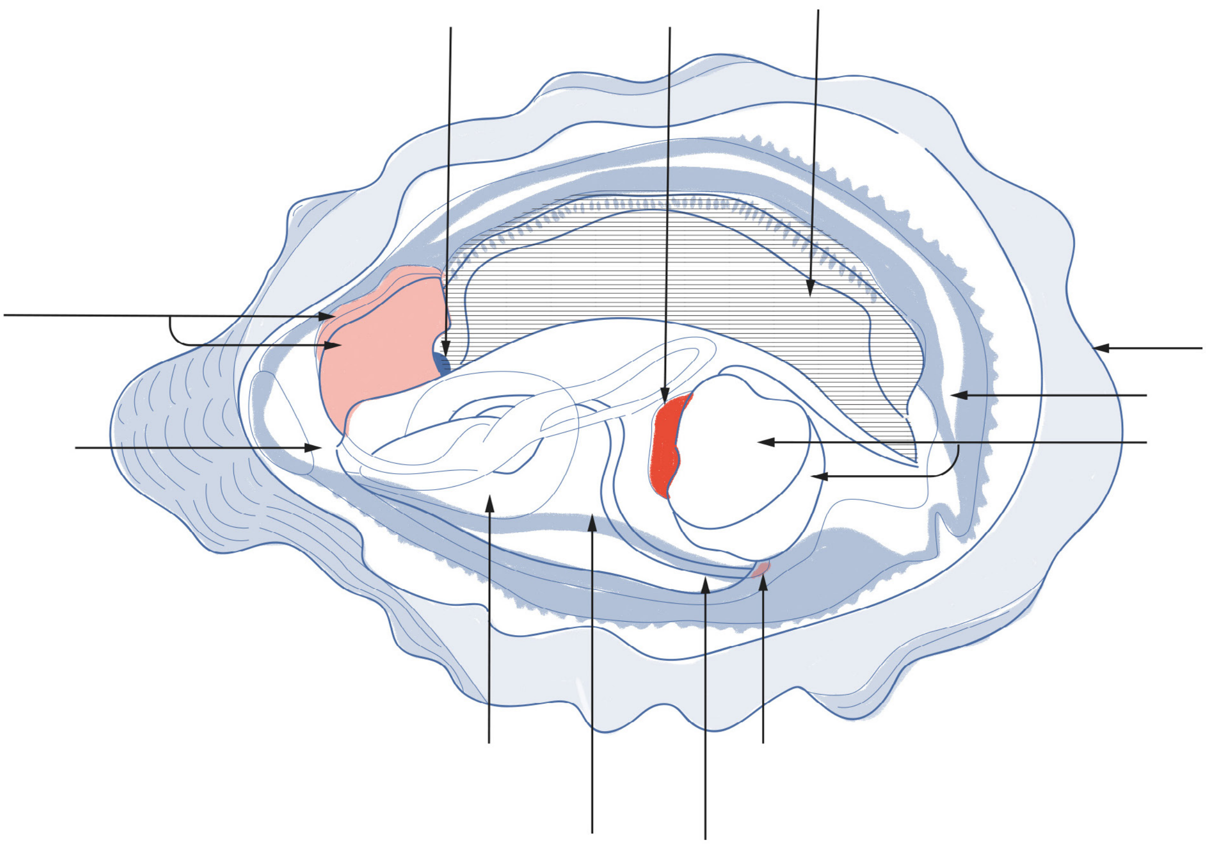
NAME ______________________ DATE ______________________

Oyster Anatomy Diagram

The Eastern Oyster

Crassostrea virginica

Please label the diagram using the key below.



Key

- ☐ Mantel
- ☐ Gills
- ☐ Palps
- ☐ Mouth
- ☐ Heart
- ☐ Adductor muscle
- ☐ Stomach
- ☐ Intestine
- ☐ Rectum
- ☐ Anus
- ☐ Shell
- ☐ Cerebal Ganglion

NAME ______________________ DATE ______________________

Oyster Anatomy Diagram

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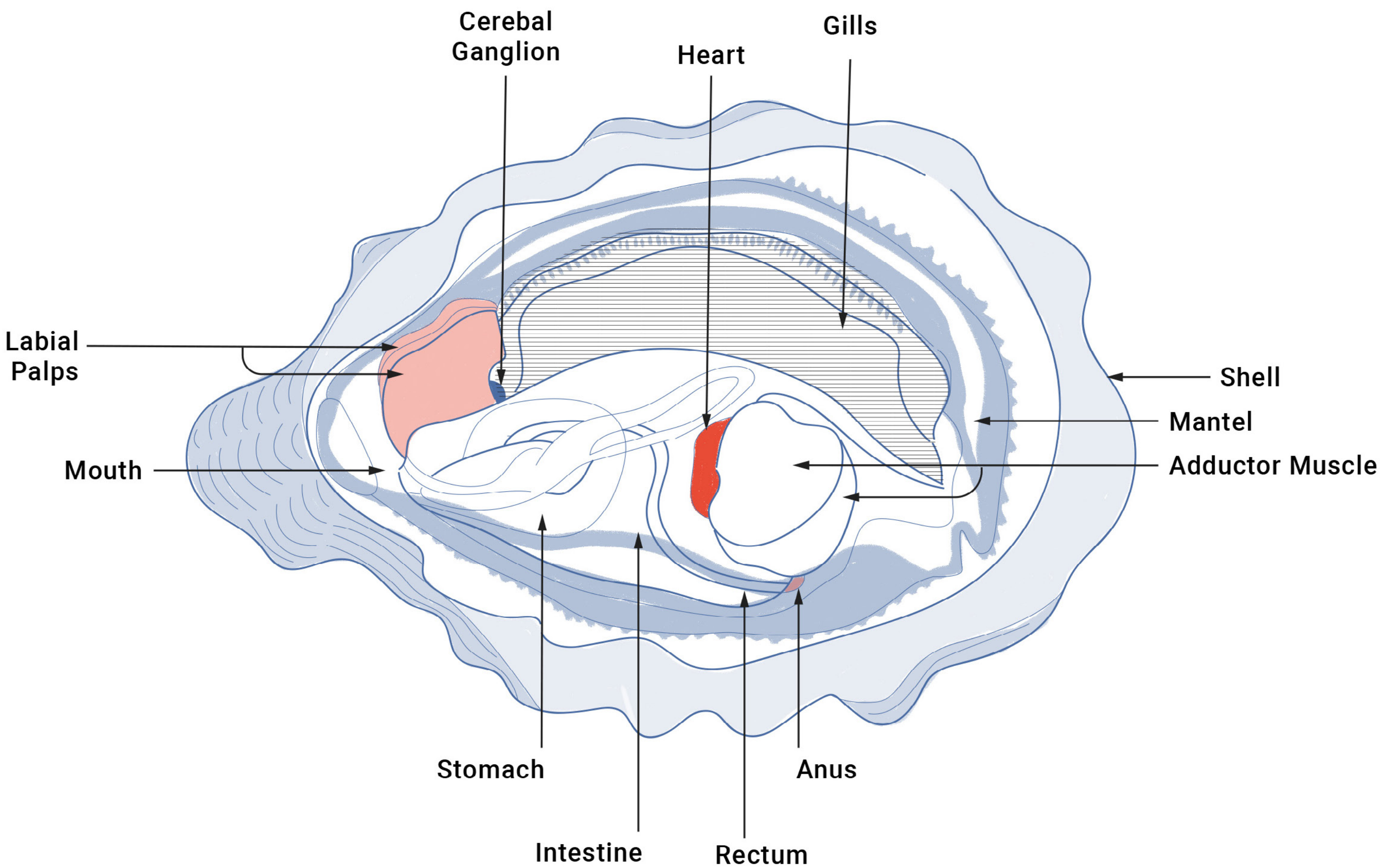

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- ☑ Cerebal Ganglion

Lesson Two

Cleaning vs. Clearing - What Happens When Oysters Eat?

Lesson Overview

Grade: 4-10
Class Periods: 2

Lesson Summary

Students will act out the process of an oyster eating in order to better understand that oysters don't really "clean" or "filter" the water, but in fact they clear the water of particles.

Objective(s)

- Compare the digestive system of an oyster to that of a human.
- Articulate how oysters deal with non-edible particles.
- Understand how the oysters' process of clearing the water is beneficial to other organisms.

Materials & Resources

Supplies

- Large bucket or tank
- Water
- Silicone bristle brush or scrub brush
- Orzo pasta
- Plastic beads that look like orzo (e.g. 12mm plastic oat craft beads)
- 1 oyster shell
- Duct tape - grey
- Duct tape - brown

Handouts

- What Happens When Oysters Eat?
- Oyster Anatomy Diagram (from Lesson One)
- Labial Palps Diagram
- Feces vs. Pseudofeces
- An Oyster Reef Habitat (from Lesson Four)

Lesson Materials

- YouTube Video - Oyster Filtration
    - https://www.youtube.com/watch?v=saAy7GfLq4w
- YouTube Video - Oyster gills in action - How an oyster feeds itself
    - https://www.youtube.com/watch?v=BFTTRZEdXno

Teacher Resources

- Particulate Matters
    -https://www.mdseagrant.org/interactive_lessons/oysters/oysfilt.htm#

Background

I heard that oysters clean the water! They're filter feeders, right?...

Well, kind of! I like to call oysters suspension feeders rather than filter feeders. That means they actually eat suspended particles, or little things floating around in the water. Oysters eat phytoplankton, which are tiny little algae/plants, but they also take in a lot of other things because they can't move or hunt for their food. So they end up bringing a lot of things into their digestive system, and sometimes they fully digest it (and poop it out the parts they can't use in feces), and other times they spit it out before it even gets into their mouths (that's called pseudofeces). Oysters draw minerals from the water mostly in the form of calcium carbonate, a substance found in many rocks. The minerals flow through the oyster's bloodstream to its mantle (a thin membrane or layer of tissue). Special glands then create a liquid substance that turn the minerals into shell. The oyster also covers the non-edible particles in this same material.

Either way, a lot of what they eat doesn't necessarily get totally cleaned out of the water, but it ends up at the bottom in the mud or sediment where they live. So oysters can help it so that fish don't eat some of the stuff floating around in the water (which can sometimes be bad like pollution or metals), but the crabs and worms and things that live in the mud will still eat some of that stuff, or at least live in or near it. So really, oysters make the water clearer, rather than cleaner.

If you think about it, that's actually what filters do too. Think about your brita filter at home, or a filter for a pool or in a fish tank. We always think about filters as cleaning the water, which they do, but really what they're doing is absorbing the dirt and stuff we don't want to drink or swim in. Filters don't last forever, right? Nope! We have to clean them out every month or so, because they get filled up with all of the gunk and stuff we don't want to drink. Oysters are a lot like that - if they keep living in really polluted waters, they can help clear some of the bad stuff out of the water in the immediate sense, but eventually, they might get sick from all the pollution, since all that pollution (like microplastic) would affect their ability to actually grow and make babies. And even if they don't get sick, they're still absorbing all that pollution, which is why we can't eat oysters that live in polluted areas like New York Harbor -- that could make us sick! So oysters definitely help clear bigger particles out of the water, but they can't make much of a difference if there's already a lot of pollution where they live. One thing they always do no matter what, though, is create really good habitat for other animals.

Also, parts of the digested product are feces or pseudofeces, which are suspended solids that are bundled, and then used by other organisms on the oyster reef for food. The filtered water then flows out of the oyster through the other hole or siphon. An adult oyster can filter up to 5 liters or 1.3 gallons of water an hour. That's equal to 60 two-liter soda bottles a day, just for one small oyster.

Instruction Plan

Engage

Students watch a video of oysters feeding and discuss what happens to the water.

1. Show the whole class the time-lapse video demonstrating oyster filtration:
    - YouTube video - Oyster Filtration
2. Each student receives an Oyster Anatomy Diagram and What Happens When Oysters Eat? worksheet.
3. Students get into pairs to complete their worksheet.
4. Bring the class together to discuss the worksheet.
5. Replicate the Oyster/Human Eating Flowchart on a class chart that everyone can see and discuss similarities and differences between the eating process of oysters and humans.

Explore

Students work in teams to act out the process of an oyster eating.

1. Split the class into teams. Each team should have approximately 9 students and each student should be assigned a "role" below.
   - Note: if teams need to be a slightly different size, one student can play two roles, or two students can play a single role.

Role	Function	Student Action
New York Harbor	Algae and other particles float in suspension and are moved by the current.	Puts orzo and plastic beads into a bucket of water and stirs.
Cilia on the gills	Specialized cilia on the gills "pump" and draw water into the shell. Other cilia on the gills trap particles with mucus.	Uses silicone bristle brush to get the orzo and beads out of the water.
Gills	Funnel particles up the side of the gills toward the labial palps.	Gets orzo and bead "particles" out of the brush and passes particles to the labial palps.
Labial palps	The palps are lip-like structures which sort the particles by both density and size. Directs edible phytoplankton and algae toward the mouth to be ingested and non-edible particles (like sediment) are towards the mantle cavity.	Sorts orzo from the beads. Passes the orzo to the mouth and passes the beads to the mantle cavity.
Mouth	Ingests the algae.	Passes orzo to the stomach.
Mantle cavity	Covers non-edible particles in mucus. Ejects them as pseudofeces .	Tightly covers the plastic beads in grey duct tape and then drops them back into the bucket where they sink.
Stomach	Digests the algae.	Breaks orzo in half and sends all halves to the small intestines.
Small intestine	Absorbs nutrients.	Places half of the orzo pieces next to the oyster shell to represent nutrient absorption and shell growth. Passes the other half of the orzo pieces to large intestine.
Large intestine	Releases feces.	Tightly covers remainder of orzo pieces with brown duct tape (to represent feces) and drops this feces into the bucket where they sink.

2. Write students' names next to the corresponding body part on the class version of the Oyster/Human Eating Flowchart.
3. Organize teams and materials and begin oyster eating process!
   - Consider making this activity a race. For example, teams could win by correctly sorting all the particles first.
4. Debrief with the class Oyster/Human Eating Flowchart.
   - In what ways was oyster eating process that you acted out accurate/inaccurate?
   - What steps or information could we add to the flowchart to make it more accurate?

Explain

Students review how the oysters actually clear the water.

1. Each student receives an Oyster Anatomy Diagram and a Labial Palps Diagram.
2. Show the whole class the video that shows the oyster cilia and gills in action:
   - YouTube Video - Oyster gills in action - How an oyster feeds itself
3. Students illustrate the process of the oyster eating by coloring in, drawing arrows, adding additional information on both diagrams.
4. Review: An oyster draws in water over its gills through the pumping of cilia (hair-like structures). Suspended food (algae) and other particles (sediment, microplastics) are trapped in the mucus of the gills and transported up to the labial palps (near the hinge).
5. Explain: The labial palps (which we could not see in the video) are super complicated!
   - The palps have two layers of tissue (inner lip and outer lip).
   - The palps have a few different features that allow them to sort particles.
   - Palps have cilia on the surface of their cells. They also have, mucous, ridges, and they are muscular. The cilia can generate currents and move particles. The mucous can trap particles. The ridges can allow for different directions of particle movement along the palps. The fact that the palps are muscular allows them to act like "arms" that can move particles towards the mouth.
   - The palps will sort particles based on size and density (if a particle is too big or heavy to enter the mouth it will be rejected).
   - The palps direct algae to the mouth, where it will be eaten, digested and expelled as feces. Other particles that the palps come across will be sent to the mantle, covered with a material similar to the oyster's shell and ejected as "pseudofeces" (i.e. false feces).

Extend

Students mimic the work of the labial palps by trying to sort different "particles"

1. For each pair of students, prepare a cup of various, small edible and non-edible "particles"
   - edible items (e.g. pumpkin seeds, pine nuts, rice, split peas)
   - non-edible items (lego, plastic, wooden or glass beads)
2. Teammate A is given the cup of "particles"
3. Teammate B closes his/her eyes and pulls particles out of the cup one by one.
4. Teammate B has to figure out a way to tell whether the item is edible or not. This student can feel, smell, or possibly even taste the items.
5. Teammate B has to sort the "particles" into an edible pile and non-edible pile.
6. Teammate A makes sure Teammate B has eyes closed and is not cheating.
7. Review sorting results with the class.
   - What other sense or tools would have been helpful in sorting the particles more accurately and quickly?
   - What items were the hardest to tell apart?
8. Explain: Microplastics are a problem for oysters.
   - Scientists think that because microplastic particles are often about the same size and density as phytoplankton (algae) that oysters consume, they eat the microplastics without understanding that they're different.
   - Based on laboratory studies, oysters that are exposed to and consume microplastics have lower growth and reproductive rates.

Elaborate

The class debriefs the process of the oyster eating and expelling feces / pseudofeces.

1. Each student receives a Feces vs. Pseudofeces worksheet and An Oyster Reef Habitat diagram.
   - How will the benthic layer (bottom sediment) surrounding an oyster reef (a whole bunch of oysters living together) look after oysters have eaten?
   - How could other organisms benefit from what the oysters expel?
   - How does the process of oysters eating affect the ecosystem?
2. Discuss the benefits of the oysters building a reef and living together in a concentrated area.

Education Standards

Next Generation Science Standards - Disciplinary Core Ideas

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

LS1.D: Information Processing

- Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. Animals are able to use their perceptions and memories to guide their actions. (4-LS1-2)

LS1.C: Organization for Matter and Energy Flow in Organisms

- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7)

Next Generation Science Standard - Science and Engineering Practices

Developing and Using Models

- Use a model to test interactions concerning the functioning of a natural system. (4-LS1-2)

Next Generation Science Standards - Cross-Cutting Concepts

Systems and System Models

- A system can be described in terms of its components and their interactions. (4-LS1-1),(4-LS1-2)

Energy and Matter

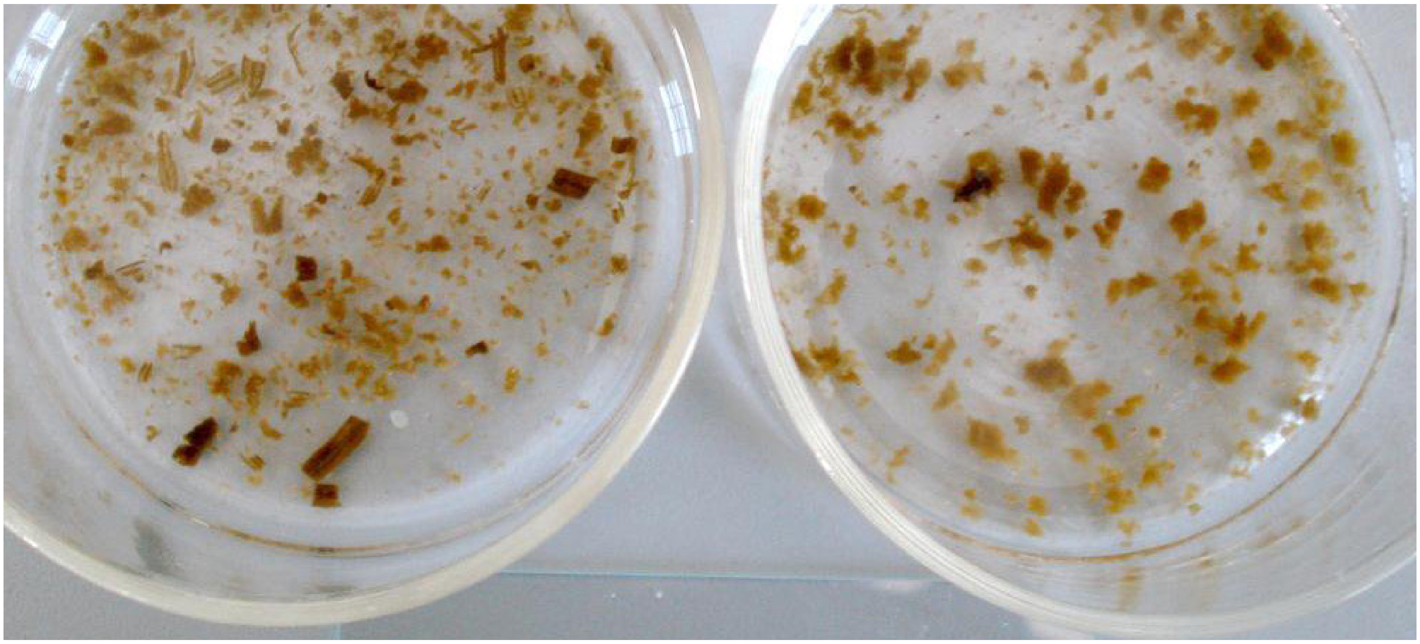
- Matter is transported into, out of, and within systems. (5-LS1-1)
- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS1-7)
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-4)

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-3)

NAME ______________________ DATE ______________________

Oyster Feces vs. Pseudofeces



Oyster Feces **Oyster Pseudofeces**

1. Consider the photo above and the Oyster Reef Habitat diagram. How will the benthic layer (bottom sediment) surrounding an oyster reef (a whole bunch of oysters living together in a habitat) look after oysters have been eating?

2. How could other organisms benefit from what the oysters expel? Consider any prior knowledge you have about food chains and food webs.

3. How does the process of oysters eating affect the ecosystem?

NAME ______________________ DATE ______________________

What Happens When Oysters Eat?

1. In the “Oyster Filtration” video, what happened to the water in the tank with the oysters?

2. In the tank with the oysters, where do you think all the stuff went that was making the water dark green?

3. What can you not see in this video? (for example: what is happening inside the oyster?)

Coffee filter

Fish tank filter

4. How does a human-made filter work? How does water move through it?

NAME ______________________________ DATE ______________________

What Happens When Oysters Eat?

5. How do you think water moves through an oyster?

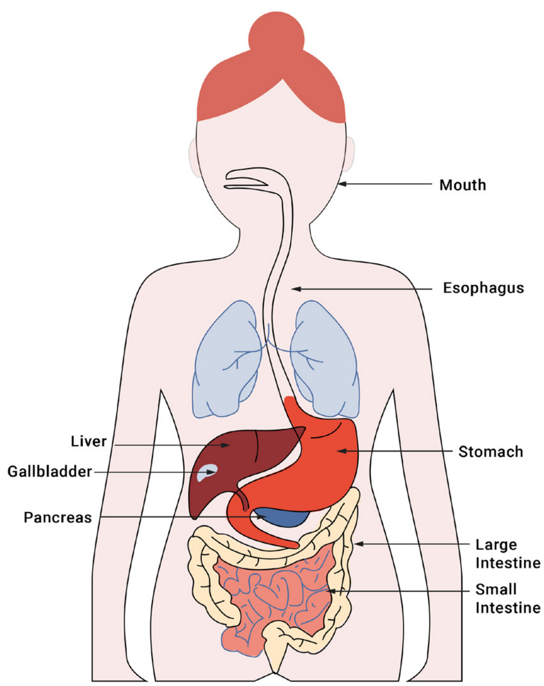
6. What happens to the human filters above after they've been filtering for awhile? Where does the filter end up? How does that compare to an oyster that's been filtering for awhile?

7. Use the human digestive system diagram below and your Oyster Anatomy Diagram to complete the flowchart below.

NAME ______________________ DATE ______________________

What Happens When Oysters Eat?

Human body part	Steps of Eating	Oyster body part
	Locate food ↓	
	Obtain (grab) food ↓	
	Bring food toward mouth ↓	
	Eat food (and reject non-edible particles) ↓	
	Digest food ↓	
	Absorb food ↓	
	Excrete food (poop)	



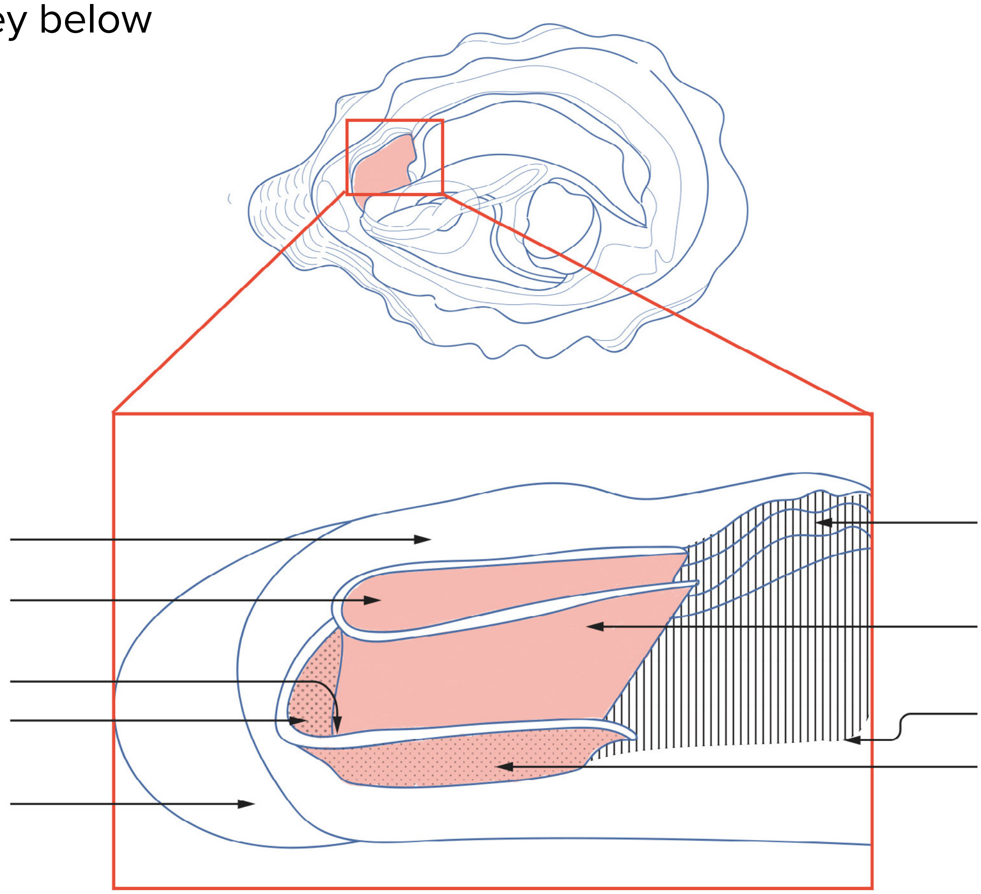
NAME ______________________ DATE ______________________

Labial Palps Diagram

The Eastern Oyster

Crassostrea Virginica

Please label this Labial Palp diagram using the key below



Key

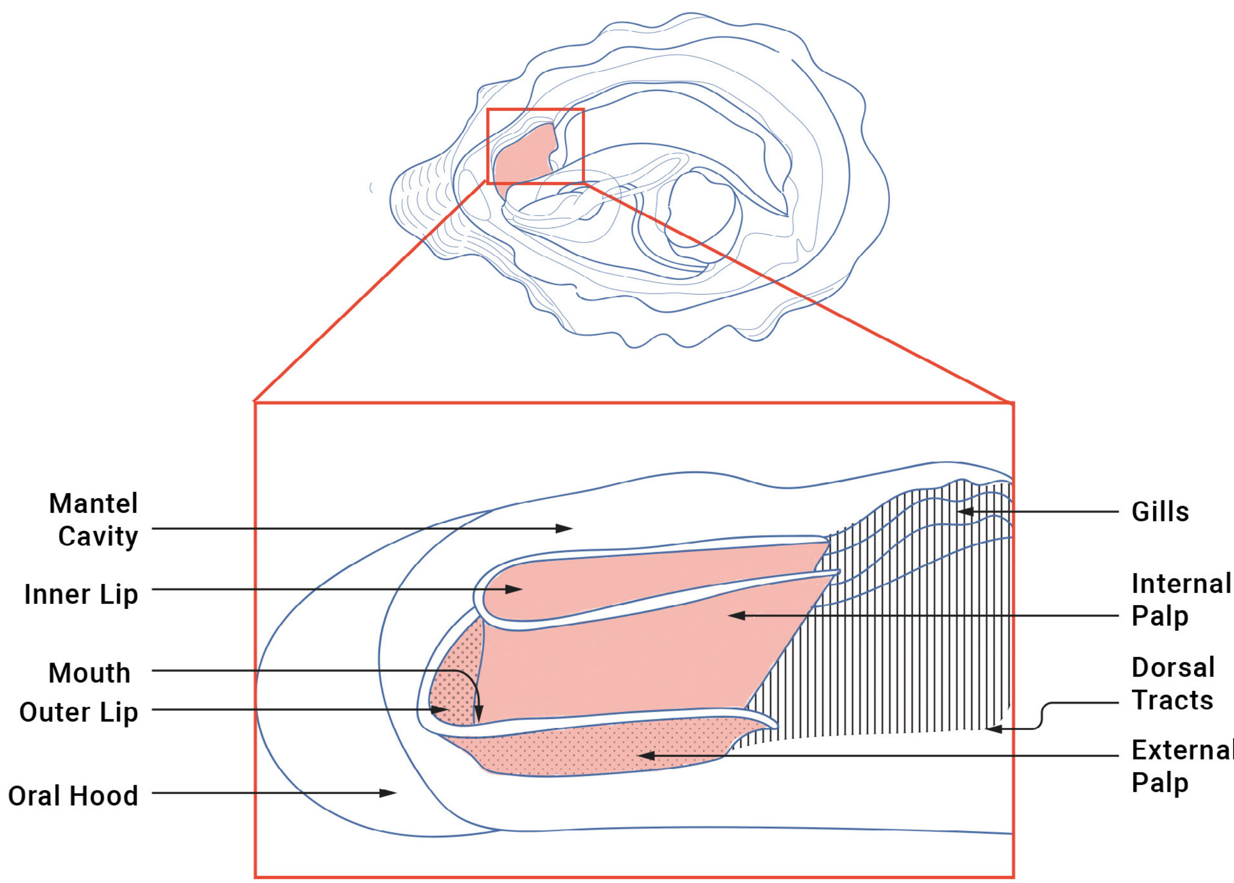
- ☐ Internal Palp
- ☐ External Palp
- ☐ Inner Lip
- ☐ Outer Lip
- ☐ Mouth
- ☐ Gills
- ☐ Dorsal Tracts
- ☐ Mantel Cavity
- ☐ Oral Hood

NAME ______________________ DATE ______________________

Labial Palps Diagram

The Eastern Oyster

Crassostrea Virginica



Key

- ☑ Internal Palp
- ☑ External Palp
- ☑ Inner Lip
- ☑ Outer Lip
- ☑ Mouth
- ☑ Gills
- ☑ Dorsal Tracts
- ☑ Mantel Cavity
- ☑ Oral Hood

Lesson Three

New York Harbor Food Web

Lesson Overview

Grade: 4-10
Class Periods: 3

Lesson Summary

Students will learn about the biodiversity of oyster reefs by each playing the role of an estuary organism. Together the class will create an estuarine food web with string, connecting the organisms to each other.

Objective(s)

- Identify at least two organisms found in New York Harbor.
- Understand that organisms within an ecosystem are dependent on each other.
- Articulate the energy transfer from one organism to the next.

Materials & Resources

Supplies

- New York Harbor Food Web Cards
- String (depending on how many students you have you may need a couple hundred yards and it's always good to have extra)
- Clipboards (one for every student)
- Scissors
- Basic classroom supplies like markers and paper

Handouts

- Food Web Questions
- Food Web Sketch
- New York Harbor Food Web

Before You Get Started

Tips for Teachers

- You will have more success with this activity if you take the time to read through all the

Food Web Cards, familiarize yourself with them and decide if you want to use them all. Consider printing more than one card for species that are abundant, such as diatoms and amphipods.

- Each student should have ONE Food Web Card.
- Use the phrasing “x gets energy from y” instead of “x eats y” in order to emphasize that one important aspect of a food web is the fact that is depicts the energy flow in an ecosystem.

Preparation

- Food Web Cards should be printed with the photograph on one side of the card and the information on the other side of the card.
- All cards should be laminated, hole punched and strung, so they hang around a student’s neck. This allows the students to be hands-free during the activity.
- Decide beforehand how you will assign each student their card. Randomly? Based on students’ prior questions or interest?

Background

The food chain begins with producers, organisms such as green plants, that can make their own food. Through photosynthesis, producers convert solar energy to chemical energy. Out of all the energy a plant receives from the sun, only about three percent is converted into chemical energy.

Plants are eaten by consumers, which are organisms that cannot make their own food. Herbivores are consumers that eat only producers. Consumers that prey on other consumers are called carnivores. If an animal can get its energy by ingesting both producers and consumers, it is an omnivore.

A food chain does not consist of a set amount of energy that is passed along like a baton from one organism to another. In reality, the ‘baton’ gets smaller and smaller with each transfer. When an herbivore eats a plant, it does not get all the energy that the plant captured from the sun. This decrease is only partly due to the fact that the herbivore may not eat all parts of the plant, or it may not be able to digest all of what it does eat. These undigested plant parts are excreted as waste.

The main reason that much of the energy obtained by one organism isn't passed on in the food chain is because it is no longer available. Some energy has already been used by the first organism. A plant uses some of the energy it receives to grow and function. A herbivore uses its energy to grow, but also to look for food and run away from predators. A predator uses large amounts of energy to chase after its food in addition to its regular life processes (e.g., breathing, digesting food, moving). The energy these organisms use leaves their bodies -- and eventually the Earth -- in the form of heat.

Instruction Plan

Engage

Students access prior knowledge about organisms in New York Harbor and learn about one particular organism from NY Harbor.

1. If you have taken your students on an expedition to your Oyster Research Station (ORS), have an oyster tank or your students have had another experience with organisms from New York Harbor begin with the following line of questions:
2. What organisms did you see?
3. Where exactly did you observe the organisms? Were they attached to something? Crawling on something?
4. From where do you think this organism gets its energy?
5. Who do you think receives energy from this organism?
6. Remind students: The most important function of oyster reefs in New York Harbor is providing a habitat (three-dimensional structure) for other organisms. Oyster reefs help increase biodiversity.
7. Each student gets one Food Web Card. (Do not pass out 'Bacteria' or 'Detritus' yet.)
8. Give the students time to familiarize themselves with the information on their card.
9. Consider providing various species ID guides for the students to read more detail about their organism, especially if you hear a lot of great questions.
10. Students present their organism to a partner or small group, in order to reinforce what they have learned.

Explore

The class works together to create a model of a New York Harbor food web.

1. Once the students are familiar with their card, it's time to get in a circle.
2. You will need enough space to get your whole class standing in a circle, with nothing in the middle of the circle. You could move desks out of the way in the classroom, go outdoors, or go into a gymnasium.
3. Make sure each student has the card around his/her neck.
4. Stand in the middle of the circle and explain: You are going to create your own food web. The string represents energy transfer between organisms.
5. Ask: In this food web, where does the energy originate? (Note: There are some food webs where the source of energy is hydrothermal vents on the seafloor.)
6. Give 'The Sun' the end of the string.
7. The students look at their cards to figure out who gets energy from the sun.
8. Based on the responses, connect the string to an organism - and another, and another, and another - until you get to a top-level consumer and a food chain has been created.
9. Ask: What should happen to the string now?
10. Solicit ideas from the students.
11. If necessary explain: In this food chain, the energy that was originally captured from the Sun by a primary producer (plant or algae) is now in the process of transferring from organism to organism up the food chain. Some of the energy is also being converted to heat. The heat will leave the Earth as radiation, the same way it arrived on Earth as radiation from the Sun. The string represents energy transfer, so there should come a point where we need to start again at the sun.
12. Cut the string and use a new piece of string to start at 'The Sun.'
13. Continue with this process until everyone in the class is holding at least one piece of string. (It's okay if some students are connected to the web multiple times, and some are only connected once).
14. Explain: We have just created a food web - a representation - a model - of how energy moves through organisms in an ecosystem.
15. Ask: What are the benefits and limitations of this model? What parts of the energy transfer process does it help us understand better"? What parts of the process are still unclear or confusing?

Extend

The class explores where decomposers belong in their food web model.

1. For a more in-depth discussion add in the 'Bacteria' and 'Detritus' cards after the first food chain is created.
2. Discuss decomposers (i.e. bacteria) in more detail and allow students to ask questions.
3. Points to solicit or explain:
   - Sometimes decomposers don't act that quickly, and dead organic matter remains for a time in larger bits like detritus.
   - There is a difference between the cycling of matter/nutrients and the flow of energy through an ecosystem. Organisms die and get decomposed. The matter that makes up their bodies does return to the ecosystem, and become nutrients for plants (primary producers), but this food web does not represent matter and nutrient cycling.
   - Decomposers get energy by breaking down dead organisms and detritus.
4. Ask: How could we include bacteria and detritus in the food web?
5. Based on the students' suggestions, pass the string through another food chain including 'Bacteria' and 'Detritus.'
6. Ask: What are the benefits and limitations of this food web model for conveying information about decomposers?

Explain

Students synthesize information about their food web model by answering questions and completing a sketch.

1. Ask students to secure their string(s) in the clip of the clipboard.
2. Students secure their string(s) in the clip of the clipboard and place their Food Web Card on the clipboard as well.
3. On the count of three, the students put their clipboards down at their feet, thereby putting the entire food web down on the ground.
4. Students get into pairs or small groups and complete the Food Web Questions worksheet.
5. Circle up again to look at the food web and review the worksheet.

6. Consider asking the following types of questions:
    - In this food web, where does the energy originate? (the sun)
    - What types of organisms can get their energy directly from the sun? (plants, plant-like algae)
    - How do the other organisms in this food web obtain energy? (Consuming each other)
    - Once an organism has energy where does the energy go and what is it used for? (used for growth and other life processes, and eventually converted to heat energy that leaves the Earth as radiation)
7. Consider introducing vocabulary such as primary producer, omnivore and consumer.
8. Each student completes a Food Web Sketch of the food web model they've created. Be sure that the students are using labels on their sketch.

Extend

Students explore the phenomenon of energy loss by representing it within the food web model.

1. Ask: In our food web the energy transfer between organisms is represented by the string, but how is energy lost? (Energy is lost as heat into the environment).
2. What could we add to our food web that would show the energy loss from one organism to the next?
3. Students work in small groups to create a visual representation on the food web of energy loss.
4. Provide the class with basic classroom supplies like markers, paper and scissors to prompt some creative thinking about how to represent energy loss.
5. Groups take turns and present their visual representation of energy loss.

Elaborate

The class simulates what happens to the food web as a whole when there is a loss of biodiversity and certain organisms are removed.

1. The students take the string off their clipboards, pinch the string tightly between their fingers and leave the clipboards down at their feet.
2. Tug on a piece of the string at one point in the web and then another point. You can do

this several times.

3. Ask: Which students can feel the tug in other parts of the web?
4. Ask: Why is it that if you tug on the string at one point, students can feel it at another point – even if they aren't directly connected to the string you are tugging?
5. Have all the students take one small step back, pulling on their string with a little pressure, without letting go.
6. Ask: What would happen if one of these organisms was eliminated from the ecosystem? What would happen to the web?
7. Ask: Who gets their energy by consuming this organism? Give students time to think about and discuss different aspects of the question.
8. Choose an organism that has more than one string leading to it (e.g. an oyster or an amphipod or all the algae) and cut all the strings leading to it.
9. Discuss what happens to the food web and the difference in the way food web "feels" (since the students were pulling on the web with some pressure and when those strings were cut.)

Evaluate

Students analyze the strengths and weaknesses of their food web sketch and synthesize the information from the lesson to create a final draft.

1. Students get back into pairs or small groups and review their Food Web Sketch.
2. Students discuss and decide how they will represent the loss of biodiversity on their sketch.
3. Each student gets a New York Harbor Food Web diagram and in their pairs or small groups discuss the similarities between their sketch and the diagram.
4. Ask: What are some of the pros and cons of each representation of the NY Harbor food web?
5. Ask: What modifications would they make to their sketch to make it more complete or understandable?
6. Students continue to work in pairs or small groups to create a final draft of a NY Harbor food web, based on all the discussion and revisions throughout the lesson.

Education Standards

Next Generation Science Standards - Cross-Cutting Concepts

- **Cause and Effect -** Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. Cause and effect relationships may be used to predict phenomena in natural systems. Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- **Energy and Matter -** The transfer of energy can be tracked as energy flows through a designed or natural system The transfer of energy can be tracked as energy flows through a natural system. Influence of Engineering, Technology, and Science on Society and the Natural World. All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.
- **Stability and Change -** Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
- **Systems and System Models -** Models can be used to represent systems and their interactions. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Next Generation Science Standards - Disciplinary Core Ideas

- **LS2.B: Cycle of Matter and Energy Transfer in Ecosystems** - Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.
- **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** - Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological components of an ecosystem can lead to shifts in all its populations.

Next Generation Science Standards - Science and Engineering Practices

- **Constructing Explanations and Designing Solutions -** Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.
- **Engaging in Argument from Evidence -** Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

NAME ______________________________ DATE ______________________

Food Web Questions

1. Who are you in this food web? ____

2. Choose one food chain of which you are part. List all the organisms in that chain.

3. What is one organism that you depend on? __________________________________

4. What is one organism that depends on you? _________________________________

5. How are you connected to the organisms above?

6. What would happen to the organism that depends on you if you were not here in the food web?

7. How is the sun important in this food web?

8. What is one important part of this food web that is not alive, other than the Sun?

9. What are some important parts of this food web's ecosystem that are not represented here?

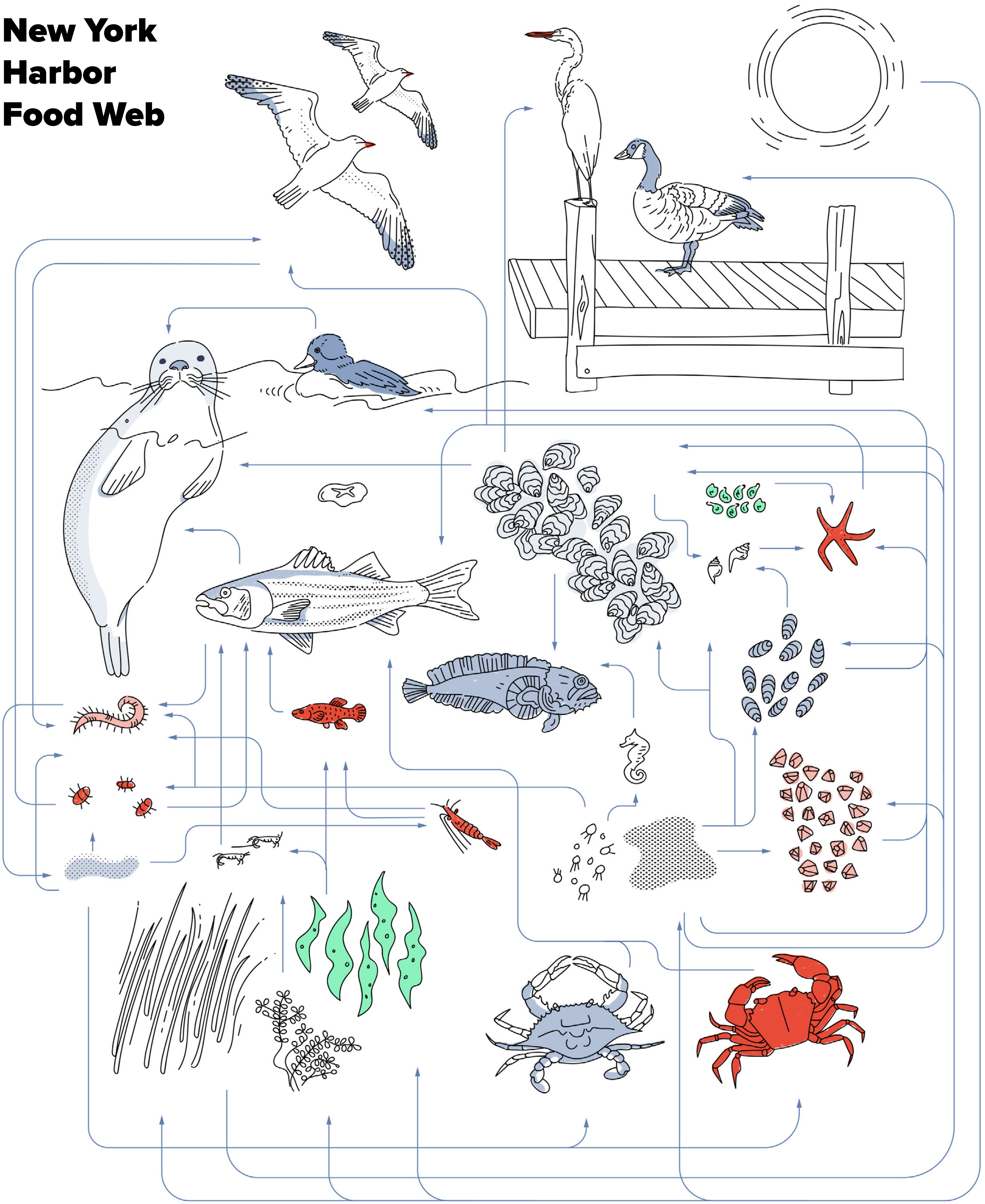
10. What do you think is the most important organism in the food web? Why?

NAME ______________________ DATE ______________________

Food Web Sketch

NAME ______________________________ DATE ______________________

New York Harbor Food Web



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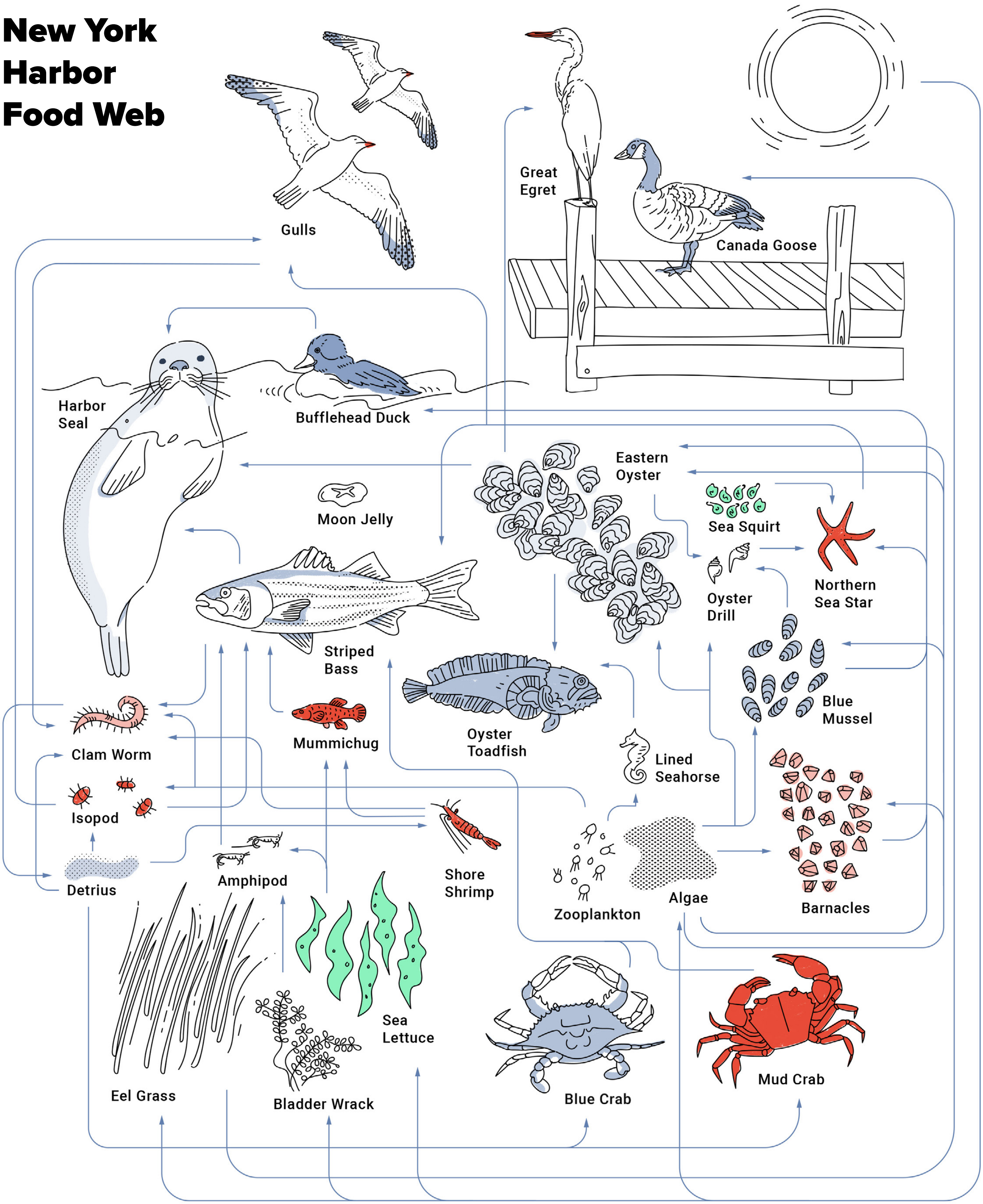
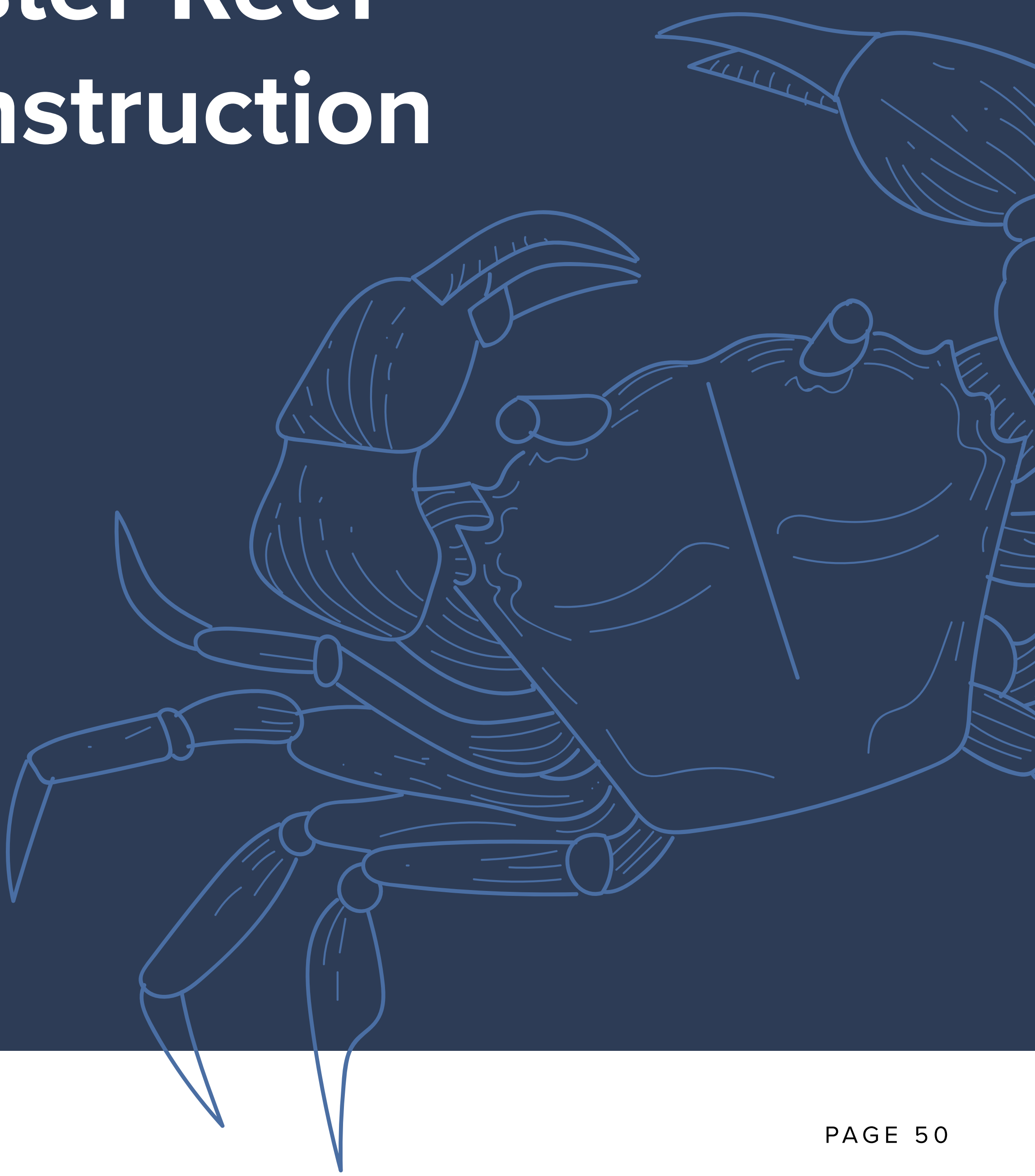
New York Harbor Food Web



Lesson Four

Oyster Reef Construction



Lesson Overview

Grade: 4-10
Class Periods: 2

Lesson Summary

Students will design and engineer their own oyster reef structure.

Objective(s)

- Describe the value of oyster reefs in New York Harbor.
- Examine different design options.
- Compare their own design with other students' designs.
- Support their design choices.

Materials

Supplies (per small group)

- Household recyclables(for example)
    - Plastic water bottle
    - Mesh bag from clementines
    - Milk container
    - Plastic berry box
    - Cork
    - Tin can
    - Aluminum pie dish
    - Plastic egg carton
- Household materials for fastening and binding (for example)
    - Tape
    - Rubber bands
    - Twist ties
    - Zip ties
    - String
- Scissors
- Oyster shells (optional)

Handouts

- Steps in an Oyster's Life
- Oysters Live Together
- An Oyster Reef Habitat diagram
- Experimental Oyster Reef Structures - Challenges and Ideas

Optional Handouts

- Piloting Oyster Reef Structures – Which Will Work Best Where in NY Harbor
- Reef Construction Examples

Lesson Materials

- YouTube Video - The Incredible Oyster Reef
    - https://www.youtube.com/watch?v=9V3yjCpIc44

Before you Get Started

Tips for Teachers

- Decide how much information you would like to give your students and at what point in the design process. Review the two optional handouts, Piloting Oyster Reef Structures and Reef Construction Examples and decide if and where in the lesson you would like to include them.

Instruction Plan

Engage

Students are introduced to how and why oysters form reefs.

1. Students receive a Steps in an Oyster's Life worksheet and complete it individually.
2. Students get together in small groups and share their sketches from the worksheet and discuss similarities and differences between their sketches.
3. Each student receives an Oysters Live Together worksheet and An Oyster Reef Habitat diagram and complete together in their small groups.
4. Come together as a class and review the students' work.
5. Watch all or part of The Incredible Oyster Reef video.
6. Students add additional information and ideas to their Oysters Live Together worksheet.
7. Discuss: Why are organisms beneficial to New York Harbor?

Explore

Students work in groups to design and build their own experimental oyster reef structure.

1. Explain: We have explored how and why oysters live together in reefs. Billion Oyster Project is working on improving its experimental reef design. Today, each group is going to design and build an experimental oyster reef structure for New York Harbor.
2. Consider watching a segment of The Incredible Oyster Reef video again, this time with the students focusing on taking notes about features they observe that they would like to mimic in their own oyster reef design.
3. Students receive an Experimental Oyster Reef Structures - Challenges and Ideas worksheet and work on it in their groups.
4. Groups receive household recyclables and fasteners with which to build their oyster reef structure.
5. Once structures are finished students can test how they sink or float in a bucket or tank of water.

Evaluate

1. Students reflect on their reef structure either in writing or by sharing out with the class.
2. They can use the following questions to guide their written response:
    - Process: What were the steps in your process? For example, how did you plan what to build? Did you make a sketch before starting? Did you test your materials before building?
    - Teamwork: How well did your team work together? For example, did everyone share ideas? Did you make decisions by consensus or was there a leader?
    - Design: Did you test your design and then adjust it as you started to build? Did you change your design completely along the way?
    - Challenges: What were the challenges you encountered?

Extend Options

1. Consider doing this lesson over multiple days so that students may collect their own recyclable materials to bring in for their design.
2. Students research New York Harbor using the maps below, in order to make a decision regarding where to put their constructed oyster reef.
    - OceanGrafix Nautical Charts - Zoom in to New York City and choose the specific chart you would like to look at. Water depths are noted on charts measured in feet.
    - NYCity Map
    - NYC Oasis Map
    - NY/NJ Harbor Estuary Map

Education Standards

Next Generation Science Standards - Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)

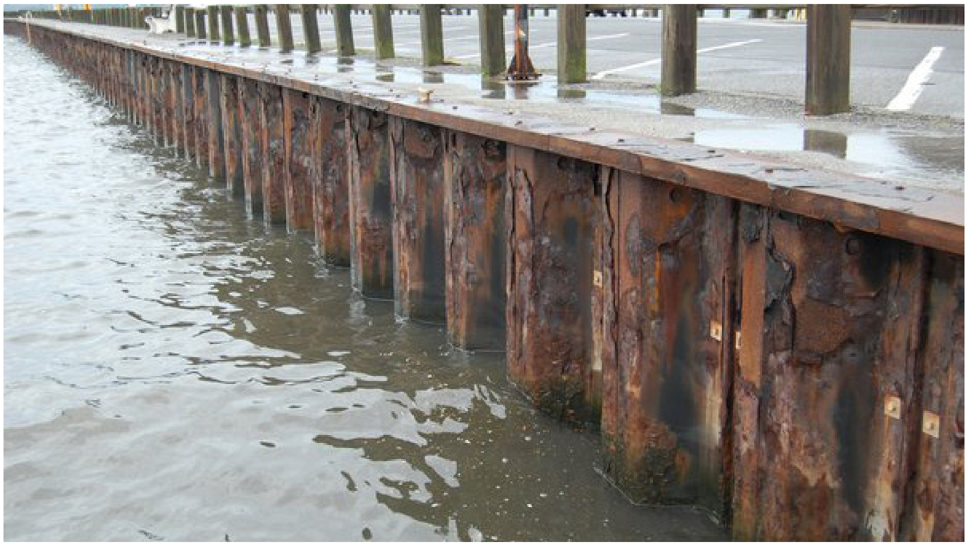
NAME ______________________ DATE ______________________

Experimental Oyster Reef Structures - Challenges and Ideas

Directions: Read the information below about some of the challenges with installing oyster reef structures in New York Harbor. Then, fill out the brainstorming section.

https://www.brownstoner.com/development/gowanus-canal-black-mayonnaise-superfund-epa-cleanup-brooklyn/

Much of the harbor's bottom is covered in a sediment that is a fine, black silt, which is like mud or clay (see left). If you put live oysters directly in this mud they won't be able to filter properly and will die.



http://www.27east.com/news/article.cfm/Sag-Harbor/572721/Sag-Harbor-Village-Board-Gets-Update-On-Long-Wharf-Rehabilitation-Pro

Much of the harbor's sides are bulkheaded (left). This means there is not much soft shore or beach leading to shallow water, which is a more ideal environment for oyster reefs. These bulkhead walls are usually made of metal, wood, rock or cement and go straight down to the bottom of the harbor.

Experimental oyster reefs need to be deep enough so that they are always covered with water (even at low tide), but shallow enough so that people can get out to the reef in order to monitor it. However, we do not want people to access the reef structure and try to eat the oysters because they may be contaminated with pathogens from combined sewer overflows or other pollutants. Eating an oyster from New York Harbor could make you very sick! So the reef structures need to well enough hidden at low tide and not easy for a curious individual to get into.

NAME ______________________________ DATE ______________________

Experimental Oyster Reef Structures - Challenges and Ideas

In the photos below, Billion Oyster Project staff members are accessing pieces of different experimental oyster reefs for monitoring.

NAME ______________________________ DATE ______________________

Experimental Oyster Reef Structures - Challenges and Ideas

Reef Structure Brainstorm

1. What are some features you would like to include in your reef structure?

2. What are some materials you think you would use?

3. What kinds of parts or pieces will you reef structure have? How will you take a piece out for monitoring? How will you secure it so it's not too easy to get into?

4. Which household materials can you use to build a model of your reef structure? What will each household material represent?

NAME ______________________ DATE ______________________

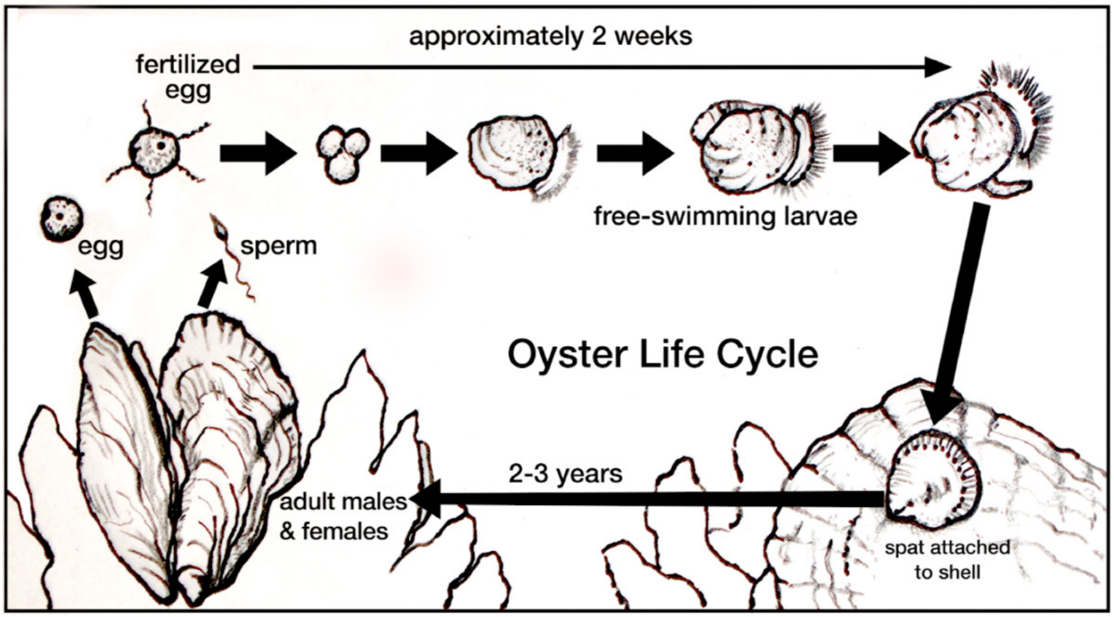
Experimental Oyster Reef Structures - Challenges and Ideas

Draw some sketches of possible designs for your reef.

NAME ________________________ DATE ________________

Oysters Live Together

Directions: Compare your sketches from the Steps in an Oyster's Life worksheet to the Oyster Life Cycle diagram below.



1. How did you do? Describe the similarities and differences between your sketches and the diagram.

2. Use your own sketches and the diagram above to create your own version of an oyster's life cycle below.

NAME ______________________ DATE ______________________

Oysters Live Together

Use the oyster life cycle and the photo above and the Oyster Reef Habitat diagram to answer the following questions.

1. How do oysters live as adults?

2. What other organisms use oyster reefs in New York Harbor?

3. Look at the photo and diagram. Why do you think the other organisms use oyster reefs? What do they use the reefs for?

4. Why are oyster reefs beneficial for the ecosystem?

NAME ______________________________ DATE ______________________

Piloting Oyster Reef Structures – Which Will Work Best Where in NY Harbor?

August 28, 2018

Part of what makes oysters such winning ecosystem engineers is their ability to reef together, creating a 3D environment where hundreds of species can thrive. Much like coral reefs, oyster reefs create habitat and can help to protect shorelines from storm damage.

In the muddy bottoms of New York Harbor, oysters need a little help to get the reef process started. Baby oysters cannot survive when sunk in the mud. So, it's important that baby oysters settle on shells (thank you, restaurant partners!), and that oysters are placed in a way that will allow them to remain close together. That's where oyster reef structures come in. They provide a stable area for oysters to live together and start growing on one another to create a reef.

Different reef structures have different strengths, and part of our work is to figure out what will work best where in NY Harbor. This process involves designing brand new structures with Harbor School teachers and students, using structures designed by others, and trying out existing structures at new locations and then making adjustments.

On Wednesday, August 15, we installed three types of reef structure never before used at our reefs. We'll monitor their performance over the next several years.

Learn more about the function of each structure below.

NAME ______________________ DATE ______________________

Piloting Oyster Reef Structures – Which Will Work Best Where in NY Harbor?

Oyster shells in bags ("bagged shell" in oyster-reef-speak)

What is it?
Standard shellfish bags, filled with juvenile oysters that have attached to ("set on") on recycled oyster and clam shells in our hatchery.

Why this structure?
Allows rapidly growing oysters to grow through the bag openings and cement together, creating a small oyster reef

Best suited for...
Near the shoreline, in calm waters

Looking forward
To reduce our use of plastic, in 2019 we will begin testing a new bag material made of coconut fiber, which is biodegradable and will breakdown overtime without adding pollutants or microplastics to our water. The only thing remaining will be our oysters.

Fun fact
We are also testing bags of "blank" shells, which means shells have no oyster babies on them. We use bags of "blank" shells in waters nearby to an oyster nursery or another reef, or where there is a wild oyster population, with the hopes that juvenile oysters in the water will find their way to the shells.

NAME ______________________ DATE ______________________

Piloting Oyster Reef Structures – Which Will Work Best Where in NY Harbor?

ECOncrete disks

What is it?
- A new substrate material designed and developed by ECOncrete Inc.

Why this structure?
- The disk's design maximizes surface area that free-swimming oyster babies (larvae) can attach to.
- Disks are cast using a mixture of materials designed to attract accreting species like oysters. Calcium and other additives, which mimic the chemical cues of oyster reefs, have been shown to increase the settlement rate of oyster larvae.
- Larvae prefer the uneven quality of the surface to flat surfaces.
- Disks can be stacked into a variety of formations.

Best suited for...
- Promotes oyster growth in the subtidal zone

NAME ______________________ DATE ______________________

Piloting Oyster Reef Structures – Which Will Work Best Where in NY Harbor?

Mini-gabions

What is it?

- A set of metal structures, the original of which was designed by our Executive Director Pete Malinowski, New York Harbor School Ocean Engineering instructor Rick Lee, and Harbor School student Marisol. This latest version was conceptualized by volunteer-welder Lucas Rockwell and then designed, engineered, and welded by Harbor School students interning with Billion Oyster Project, with support from Billion Oyster Project staff and Harbor School Welding Instructor Clarke Dennis. The sliding top is an experimental design that allows the gabions to be loaded with live oysters (vs. loaded with empty shells as is sometimes the case in waters populated with oyster larvae).

Why this structure?

- Steel gabion structures provide a strong, current-resistant 3D environment.
- The mesh (galvanized steel) holds the shells in, and outer (raw) steel is for stability and ease of lifting and moving the structures.
- In the long run, the mesh will degrade over time while the oysters cement together. Eventually the mesh will no longer be needed to maintain the structure of the reef.

Best suited for...

- Environments with current; deep waters.

All structures were installed at the Lemon Creek Lagoon Pilot Oyster Reef off of the South Shore of Staten Island. This reef is part of the activities that Billion Oyster Project's Senior Project Manager Danielle Bissett is spearheading to prepare for the eventual restoration of oysters at the Living Breakwaters Project managed by the Governor's Office of Storm Recovery (GOSR).

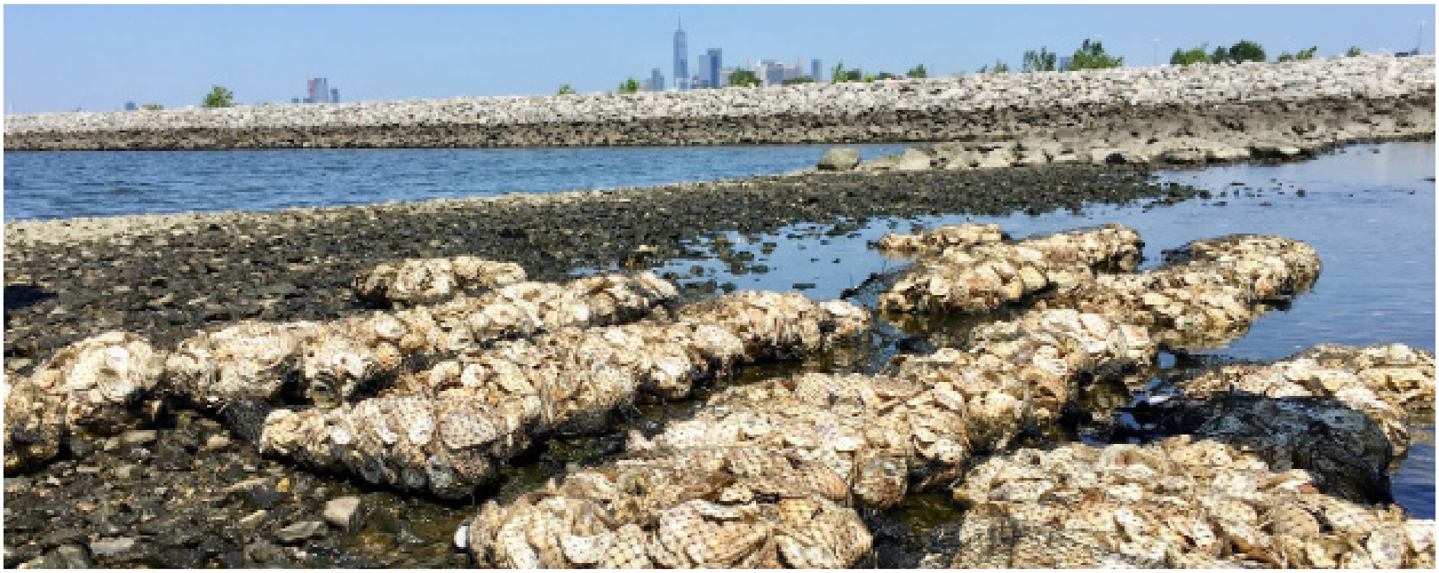
Bags of shells (with oysters and blank) are also installed at our Sunset Park: "Bagged Shell" Pilot Reef Research Project.

Source: https://billionoysterproject.org/piloting-oyster-reef-structures-which-will-work-best-where-in-ny-harbor/

NAME ______________________ DATE ______________________

Reef Construction Examples

(all photos courtesy of Billion Oyster Project unless otherwise noted)



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Reef Construction Examples

(all photos courtesy of Billion Oyster Project unless otherwise noted)

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Reef Construction Examples

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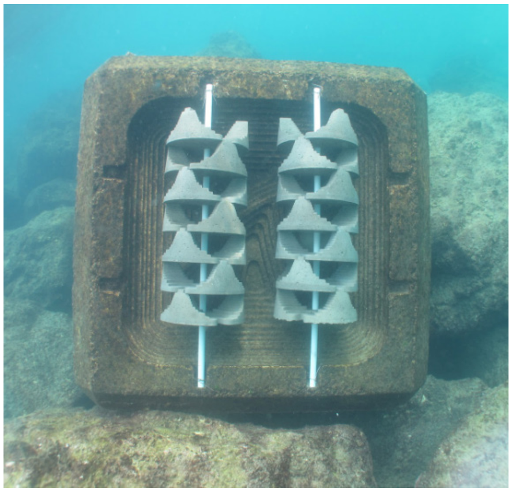

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Reef Construction Examples

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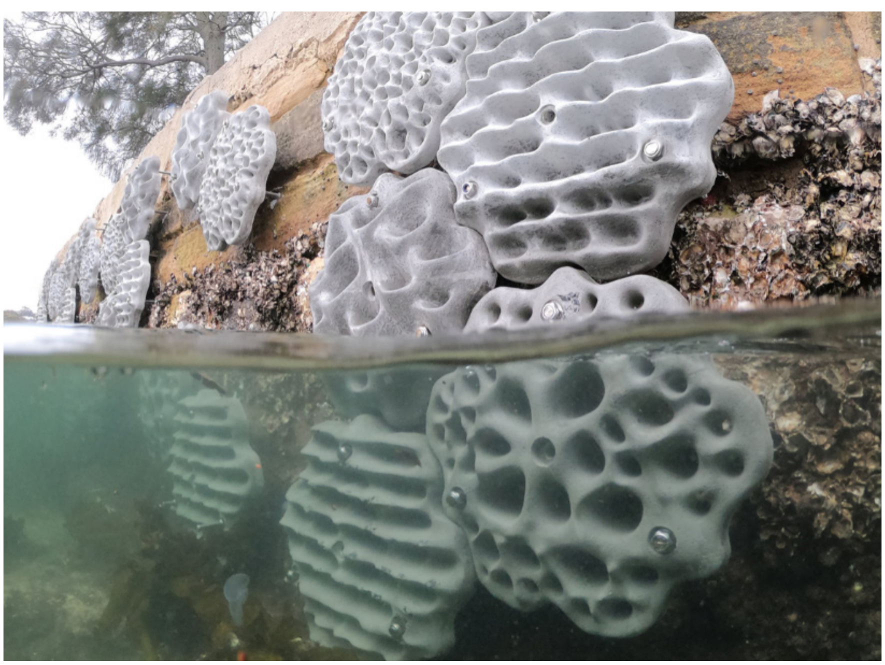

https://www.reefdesignlab.com/living-seawalls

NAME ______________________ DATE ______________________

Reef Construction Examples

(all photos courtesy of Billion Oyster Project unless otherwise noted)

NAME ______________________ DATE ______________________

Reef Construction Examples

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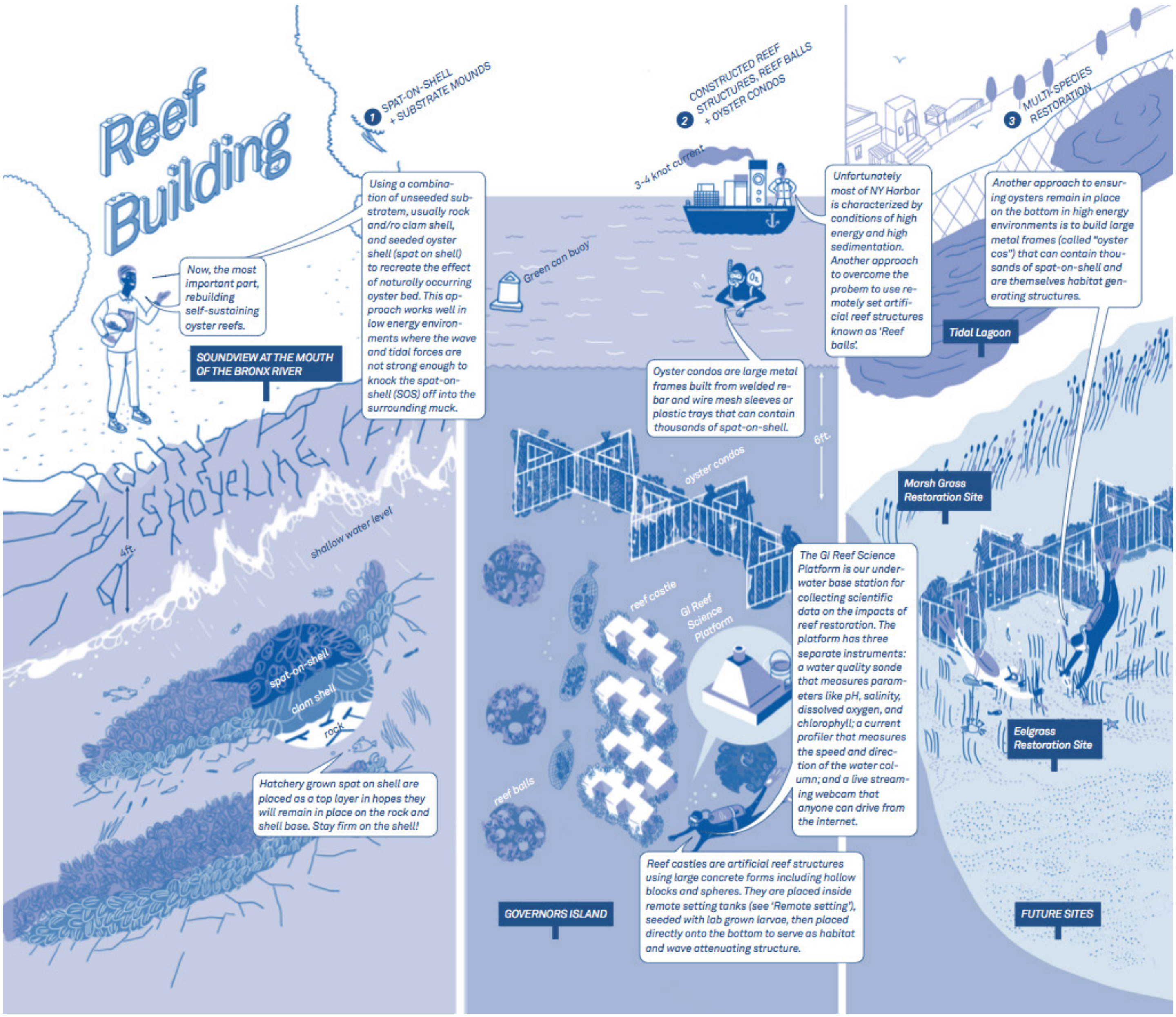


NAME ______________________ DATE ______________________

Steps in an Oyster's Life

#	Step in the Oyster's Life Cycle	Sketch
1	When adult oysters reproduce (make babies) they release eggs and sperm into the water.	
2	The eggs and sperm float around in the water. Some of the sperm find eggs and fertilize them.	
3	The fertilized egg becomes a group of cells that divide (make more cells) very quickly. This is called an embryo.	
4	Eventually, the embryo becomes an oyster larva, which is microscopic and looks like it has a see-through shell.	
5	Oyster larva lives floating around in the water for about two weeks.	

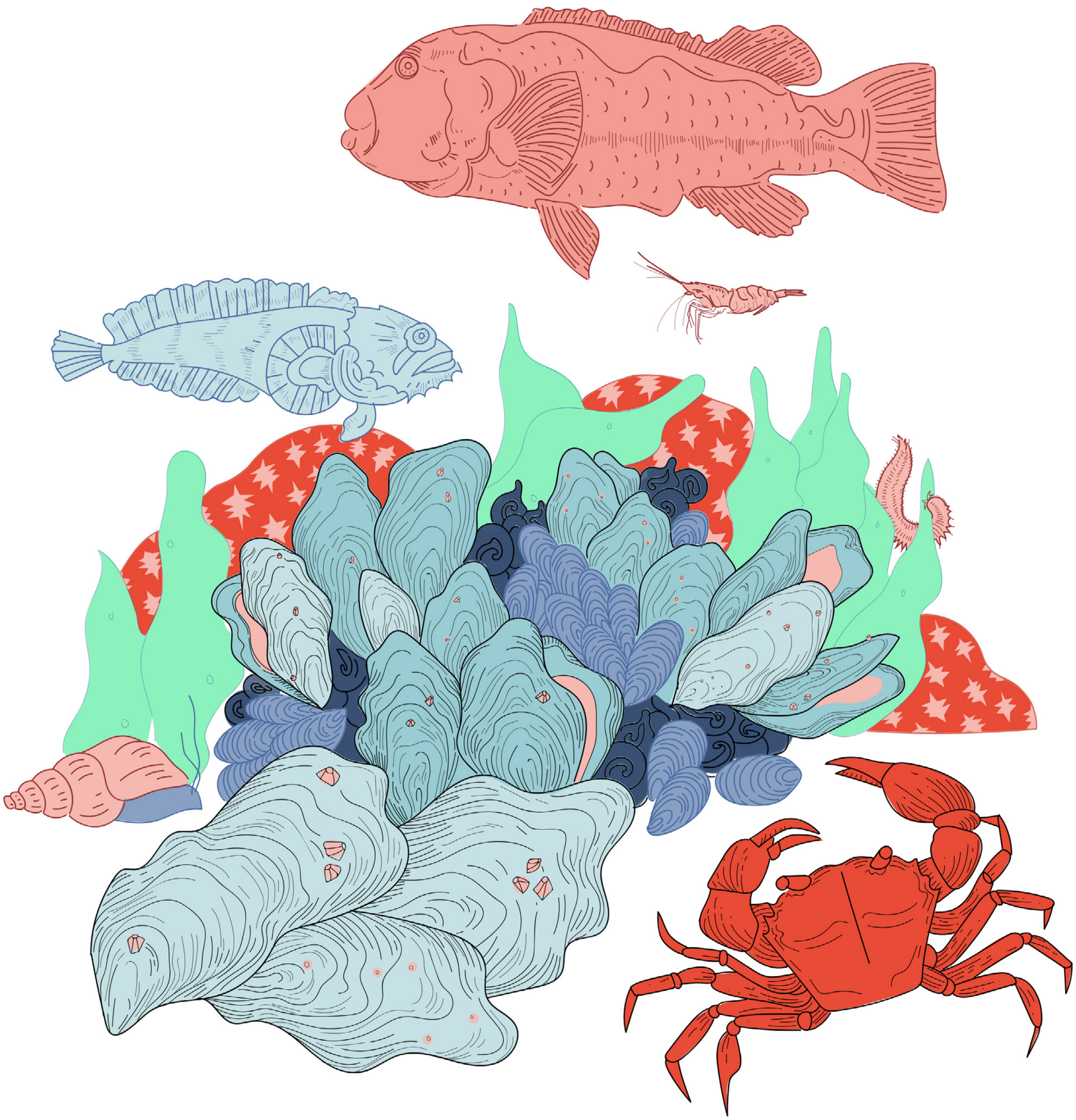
NAME ______________________ DATE ______________________

6	During this time the larva starts to grow a shell and an appendage (body part that sticks out) called a "foot."	
7	Once the larva is approximately two weeks old it goes down deeper in the water to search for a hard surface (substrate).	
8	The larva use its "foot" to help it crawl around on the bottom to find a good, hard surface (substrate) to attach to. The larva prefers other oyster shells, but it can attach to other materials such as cement,	
9	Once a larva has found a good substrate, it attaches itself by making a type of natural cement (or glue).	
10	The larva attaches to the hard surface and then it is called an oyster "spat".	
11	In about two years the oyster becomes an adult. The oyster will stay there for the rest of its life (unless something breaks it off). This is how oysters form a reef.	

NAME ______________________ DATE ______________________

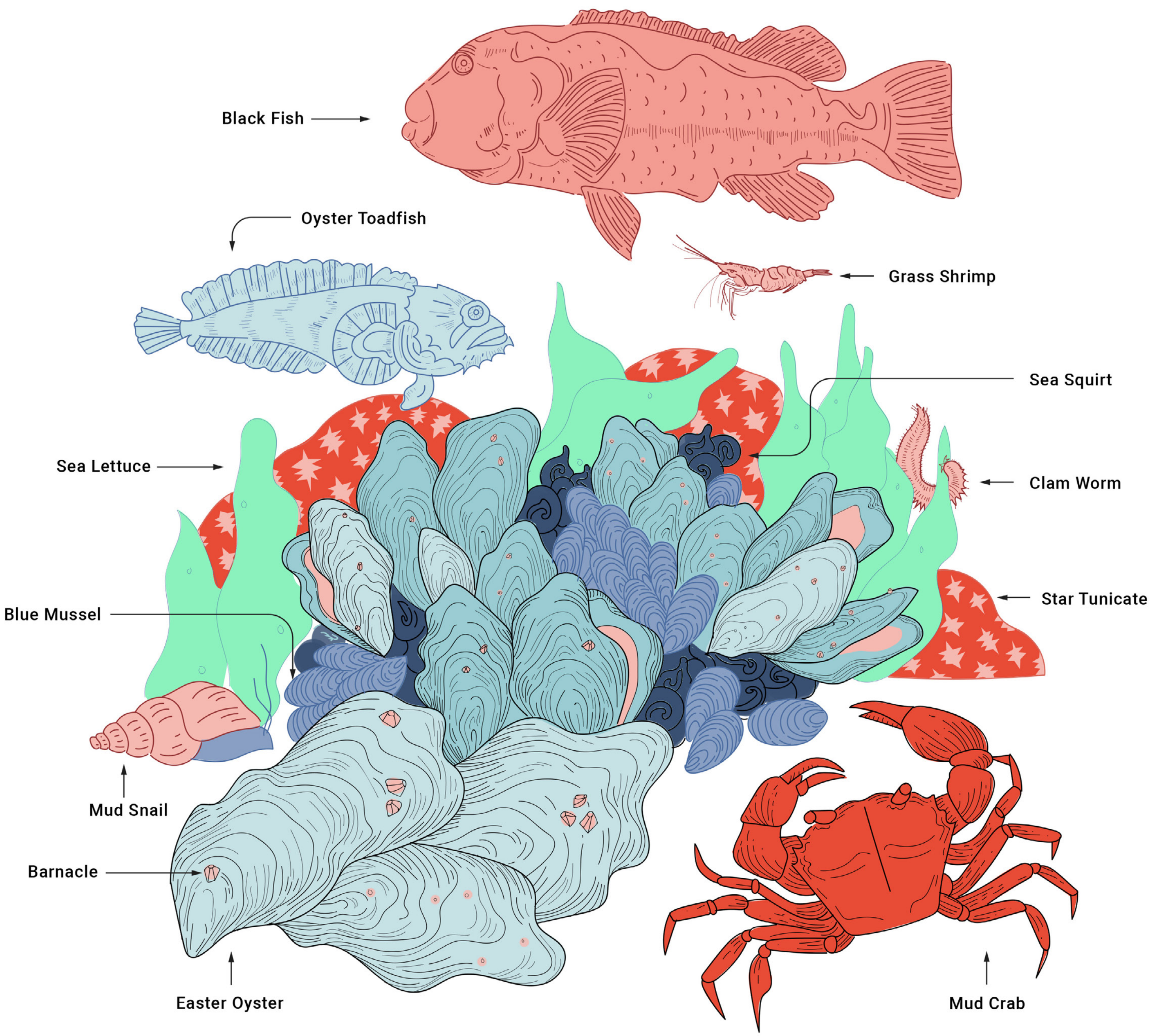
An Oyster Reef Habitat

Please label the organisms



NAME ____________________ DATE ____________________

An Oyster Reef Habitat



Lesson Five

Combined Sewer Overflows - A Barrier to Oyster Restoration

Lesson Overview

Grade: 4-10
Class Periods: 3

Lesson Summary

Students will make and explore a 3D model of a sewershed and discuss the implications of combined sewer overflows for the urban ecosystem.

Objective(s)

- Understand and explain how water flows through a sewershed.
- Understand and explain how a combined sewer works.
- Brainstorm and design a possible solution for combined sewage overflow during rain events.

Materials

Supplies (per small group)

- Yogurt (or similar plastic) container (approx. size 16oz. - 32oz.)
- Small cup
- Large cup
- Aluminum tray
- Coffee filters
- Rubber band
- Permanent marker
- Glitter and chocolate sprinkles
- Water
- Paper towels

Handouts

- DIY CSO Model
- CSO Diagram
- Sanitary . . . Sewer?
- What's in Poop?
- CSO Solutions

Lesson Materials

- YouTube Video - 9/16/2010: Storm floods Gowanus Canal with Raw Sewage
  - https://youtu.be/HzWOOqPAEgs
- Combined Sewer Overflow in Newtown Creek
  - https://vimeo.com/206785865

Teacher Resources

1. **Open Sewer Atlas NYC Resources**
   - https://openseweratlas.tumblr.com/resources
   - Printable maps and information about major sewersheds within New York City
2. **Open Sewer Atlas NYC Map**
   - https://openseweratlas.tumblr.com/map
     - Interactive map showing CSOs and Wastewater Treatment Plants in New York City
3. **New York City Water Trail Association (NYCWTA) Water Quality Data**
   - http://www.nycwatertrail.org/water_quality.html
   - NYCWTA is a not-for-profit stewardship group comprising over 20 community-based non-motorized boating organizations in and around New York City. Their citizen science water quality testing program tests for Enterococcus near the shore where both CSOs and many recreational activities take place. They test mainly during the recreational season.

Before you Get Started

Tips for Teachers

- This lesson works best with students in small groups.
- Be prepared for clean-up after this activity.

Preparation

Prep one yogurt container for each student group by carefully cutting two holes:

- a pencil-eraser-sized hole in the bottom-center of the yogurt container
- a quarter-sized hole in the side of the yogurt container approximately a half-inch up from the bottom.

Background

We never really see water flow in the city except for rain running down the street and into a drain. The concept of a sewershed is similar to that of a watershed, but reflects that instead of flowing naturally, rainwater flows into pipes where it mixes with sewage and is diverted to wherever engineers and city planners have decided it should go (which may or may not be where it would have naturally wound up).

Sometimes, during heavy rain and snow storms, combined sewers receive higher than normal flows. Treatment plants are unable to handle large flows and when storms occur,, a mix of excess stormwater and untreated wastewater discharges directly into the city's waterways at certain outfalls. This is called a combined sewer overflow (CSO). We are concerned about CSOs because of their effect on water quality and recreational uses. More than 27 billion gallons of raw sewage and polluted stormwater discharge out of 460 combined sewage overflows ("CSOs") into New York Harbor alone each year. Although water quality in New York Harbor and throughout the Hudson River Estuary has improved significantly over the last few decades, many parts of the waterfront and its beaches are still unsafe for recreation after it rains. As little as one-twentieth of an inch of rain can overload the system. The main culprit is outmoded sewer systems, which combines sewage from buildings with dirty stormwater from streets.

This extraordinary degree of pollution imposes steep environmental, human health, and economic costs. CSO discharges, in addition to preventing safe recreation, impair navigation and damage fish habitat. Combined Sewer Overflows (CSOs) discharge raw sewage contaminated with potentially pathogenic fecal bacteria into New York Harbor after as little as 1/20th of an inch of rainfall. As a huge source of pollution in New York Harbor, CSOs are a major impediment to achieving the Clean Water Act's goal of all US waters becoming "swimmable and fishable."

Instruction Plan

Engage

Students watch a and discuss video showing a combined sewer overflow event.

1. Present students with the following questions:

- What are some of the ways we use clean water in our daily lives?
- Where do you think that water goes after we use it?
- What are some of the ways people interact with the water in New York Harbor?

2. Students share answers and ideas. Prompt students to share as much as they know about what happens to water we flush the toilet or take a shower.
3. Each student gets a CSO Diagram.
4. Show the whole class one or both of the following videos showing CSO events in New York City:
   - 9/16/2010: Storm floods Gowanus Canal with Raw Sewage
   - Note for teachers: after minute 2:30 the videographer points out used condoms floating in the canal. Depending on what you think is best for your students, stopping the video at 2:30 would allow ample time for students to observe some effects of CSOs on a waterbody. Right before minute 2:00 the camera focuses on women who are visibly disgusted by the smell of the canal, which could be worth thinking about as well.
   - Combined Sewer Overflow in Newtown Creek
5. Lead the students through comparing what they saw in the video with their CSO Diagram.
   - What is going on in these videos?
   - What are some of the things you see coming out of the CSOs?
   - Which part of the diagram is being illustrated in the video?
   - Have you ever noticed anything like this at the waterfront? (Think about sights and smells!)
   - What surprised you in this video?
   - Do you think it's bad for sewage to enter NYC's waterways? Why or why not?
   - How might this affect the ways people interact with the harbor that we discussed in the beginning of class?

Explore

Students create their own combined sewer overflow system and test it using different amounts of water.

1. Students get into small groups.
2. Each student gets a DIY CSO Model worksheet.
3. Each group gets a set of supplies from the supply list and answers questions 1 - 5 while

completing the following steps:

- Place the coffee filter on the underside of the yogurt container and secure in place with a rubber band. Be careful NOT to cover the hole on the side of the container.
- Fill the small cup with water and mix in glitter and chocolate sprinkles.
- Hold the yogurt container over the aluminum tray and slowly pour the contents of the small cup into the yogurt container.
- What were the results? What happened to the water? Glitter? Sprinkles? (The coffee filter should catch the glitter and sprinkles and the filtered water should pour out of the hole in the bottom of the yogurt container into the aluminum tray.)
- Carefully compare the model to the CSO Diagram. What do the different parts of your model represent?
    - Yogurt container = sewershed with combined sewer system
    - Coffee filter = wastewater treatment plant
    - Small cup = sanitary sewer
    - Glitter = toilet paper, other items that go down drains
    - Chocolate sprinkles = feces
    - Aluminum tray = New York Harbor
    - Water coming out of hole in bottom of yogurt container = treated effluent

4. Bring the class together and discuss the students' comparison of the model to the diagram.
5. Groups use the permanent marker to write the correct labels on the different parts of the model (e.g. Write "sewershed with combined sewer system" on the yogurt container. Write "sanitary sewer" on the small cup.)
6. Groups return to their models and answer questions 6-14 while completing the following steps:
    - Replace the coffee filter with a new one if necessary.
    - Refill the small cup with water and mix in glitter and sprinkles.
    - Fill the large cup with water and mix in glitter and sprinkles.
    - Make a prediction: What will happen to the water, glitter and sprinkles when you pour both the small and large cup into the yogurt container at once? (The coffee filter should continue to catch some glitter, but some water and glitter should also flow out the hole in the side of the yogurt container.)
    - Hold the yogurt container over the aluminum tray and quickly pour both the contents of both the large and small cups into the yogurt container.
    - What were the results? What happened to the water? Glitter? Sprinkles?

- Once again, carefully compare the model to the CSO Diagram. What do the following parts of your model represent?
    - Large cup = storm sewer
    - Water in large cup = wet weather / rain
    - Hole in side of yogurt container = CSO (combined sewer outfall)
    - Water coming out of hole in side of yogurt container = untreated effluent

7. Groups review and analyze both their model and the CSO Diagram and answer questions 15 - 19 on the CSO Model worksheet.

Extend

Students complete a worksheet and engage in some wordplay around the term "sanitary sewer."

1. Each student receives a Sanitary . . . Sewer? worksheet.
2. Once students have completed it as best they can, lead a discussion about their responses.
3. Note: This is a great opportunity to engage in wordplay, a crucial part of vocabulary and literacy development.
    - In particular, it can help students develop the powerful idea that words are related to each other through shared roots, both within English (e.g. sanitary and sanitation) and between languages (particularly important information for ELLs who speak languages related to English)
    - It can also get at the irony of the term "sanitary sewer." Historically, the name reflects the fact that the sanitary sewer is far cleaner and healthier for city dwellers than no sewer at all!

Explain

Students learn about the bacteria that is released into New York Harbor through the CSOs.

1. Ask: Based on what you've learned so far, why might it be a bad thing for raw sewage to enter the harbor?
2. Students receive a What's in Poop? worksheet and work on it in small groups.

3. Discuss:
    - How might sewage and bacteria in New York Harbor make it more difficult to restore oysters and increase the biodiversity here?
    - What effect can CSO's have on people doing restoration work in the New York Harbor or on people trying to enjoy recreation on the harbor?

Extend

Students design and engineer a solution to combined sewage overflow out of household materials.

1. Note: This lesson presents a compelling problem that students may want to solve! For teachers with more flexibility to their schedule, the CSO problem could lend itself nicely to a student-driven unit in which students design solutions (or advocacy efforts) around this issue.
2. Students get into small groups and each student receives a CSO Solutions worksheet.
3. Groups brainstorm possible solutions to remediate the CSO issue.
4. Students within each group come to a consensus about which design to build.
5. Provide small groups with other household items (cardboard, straws, cups, tape, etc).
6. Students build their chosen design above and, if applicable, connect the model of their CSO solution to the original CSO model.
7. Students test their design using the water, glitter, and sprinkles mixture.
8. Students analyze their results and make improvements to their design.

Education Standards

Next Generation Science Standards - Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World

- People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1)
- Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

NAME ______________________ DATE ______________________

DIY CSO Model

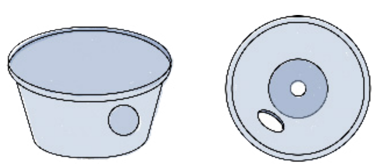
Directions:

You will make and explore a 3D model of a combined sewer overflow in order to understand how they work and why they impact New York Harbor. Follow the instructions below.

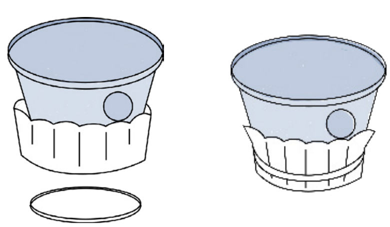
Supplies

- Yogurt (or similar plastic) container (approx. size 16oz. - 32oz.)
- Small cup
- Large cup
- Aluminum tray
- Coffee filters
- Rubber band
- Permanent marker
- Glitter and chocolate sprinkles
- Water
- Paper towels

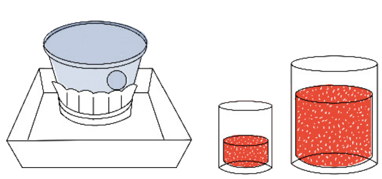
Instructions



Prep the **yogurt container**s by carefully cutting **a pencil eraser sized hole in the bottom-center** and a second, **quarter-sized hole in the side** of the yogurt container approximately a half-inch up from the bottom.



Place the **coffee filter** on the bottom of the yogurt container and secure in place with **rubberband.** Be careful **NOT** to cover the hole on the side of the container.



Prepare a small, and a large **cup** of a **water, sprinkles, and glitter mixture.** Set those aside. Set up the **aluminum tray** in the middle of the table, with your filter in the center.

NAME ______________________ DATE ______________________

DIY CSO Model

Hold the yogurt container over the aluminum tray and slowly pour the contents of the small cup into the yogurt container. **What were the results? What happened to the water? Glitter? sprinkles?**

Carefully compare your model to the CSO Diagram. What do the following parts of your model represent?

Yogurt container	
Coffee filter	
Small cup	
Glitter	
Chocolate sprinkles	
Aluminum tray	
Water coming out of hole in bottom of yogurt container	

NAME ______________________ DATE ______________________

DIY CSO Model

- Replace the coffee filter with a new one, if necessary.
- Refill the small cup with water and mix in glitter and sprinkles.
- Fill the large cup with water and mix in glitter and sprinkles.

Make a prediction: **What will happen to the water, glitter and sprinkles when you pour both the small and large cup into the yogurt container at once?**
Hold the yogurt container over the aluminum tray and quickly pour both the contents of both the large and small cups into the yogurt container. **What were the results? What happened to the water? Glitter? Sprinkles?**

Once again, carefully compare the model to the CSO Diagram. **What do the following parts of your model represent?**	
Large cup	
Water in large cup	
Hole in side of yogurt container	
Water coming out of hole in side of yogurt container	

NAME ______________________ DATE ______________________

DIY CSO Model

Sketch your sewershed model and add labels.

What parts of this diagram/model are you familiar with or have you seen around New York City?

NAME ______________________ DATE ______________________

DIY CSO Model

Based on your model and the CSO diagram, answer the following questions:

What is a sanitary sewer? What kinds of waste or pollutants might you find in a sanitary sewer?

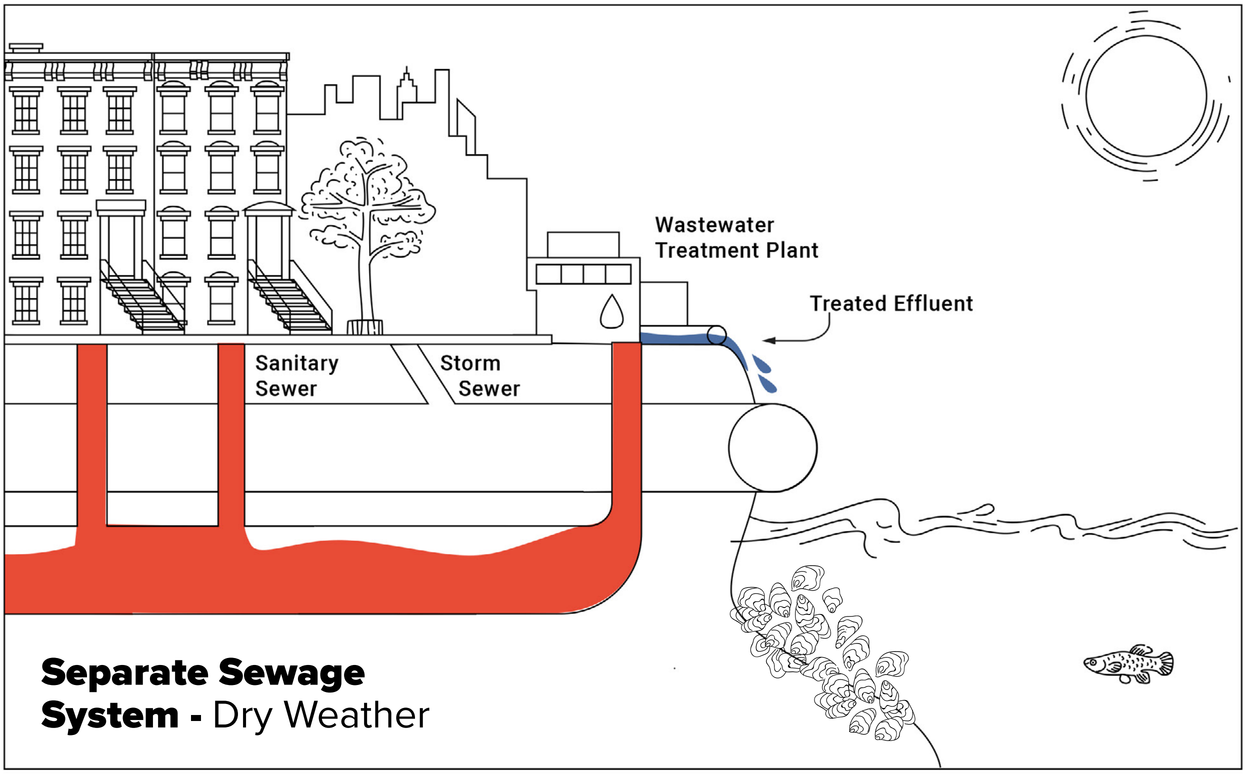
What is a storm sewer? What kinds of waste or pollutants might you find in a storm sewer?

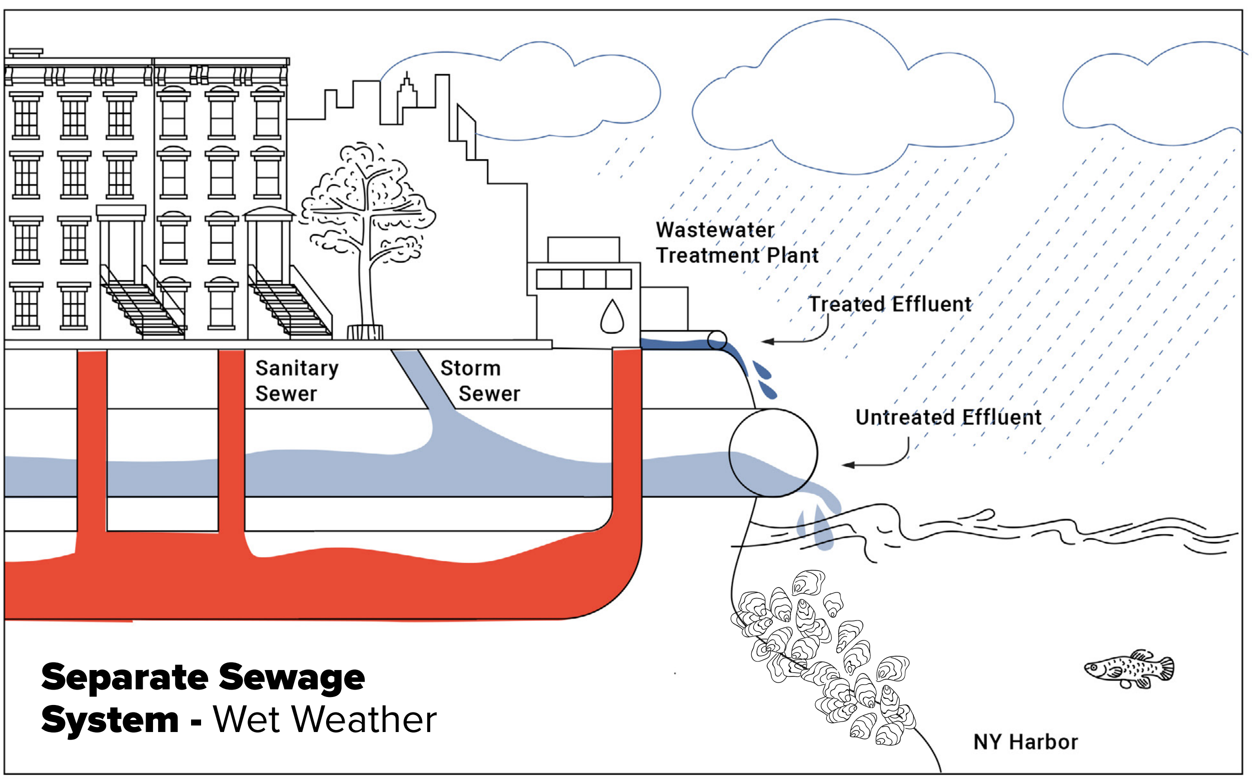
What is a combined sewer? What does it connect to? What kinds of waste or pollutants might you find in a combined sewer?

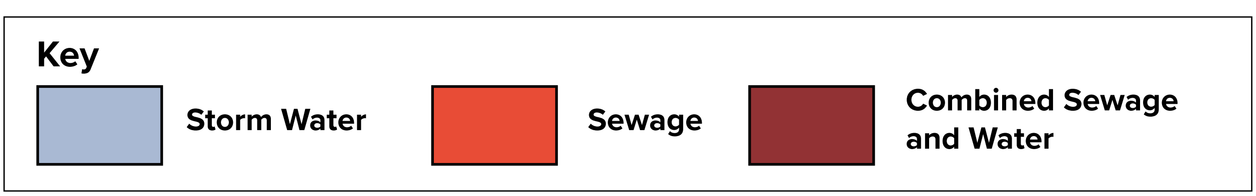
What might be the pros and cons of combining the sanitary sewer with the storm sewer? Put another way: why on earth would anyone design a sewer system that dumps more poop in the harbor? And why don't they just separate the two systems now?

Based on your model and the diagram, write a definition for "sewershed." (How is it different from a watershed?)

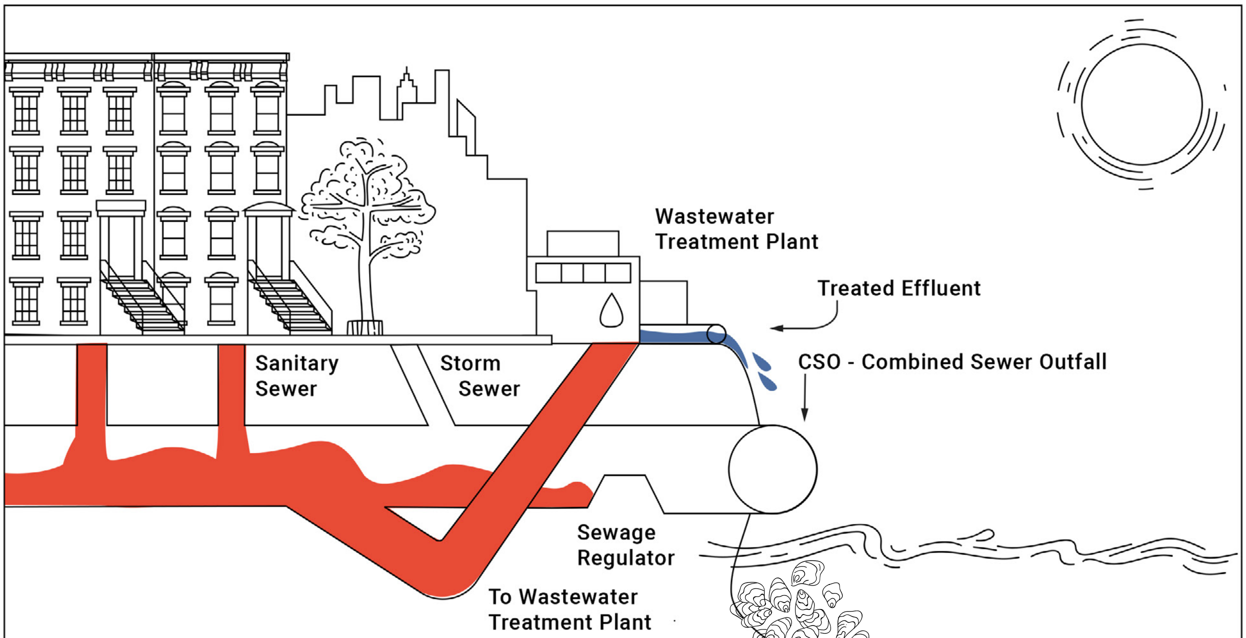
NAME ______________________ DATE ______________


Wastewater Treatment Plant
Treated Effluent
Sanitary Sewer
Storm Sewer
Separate Sewage System - Dry Weather

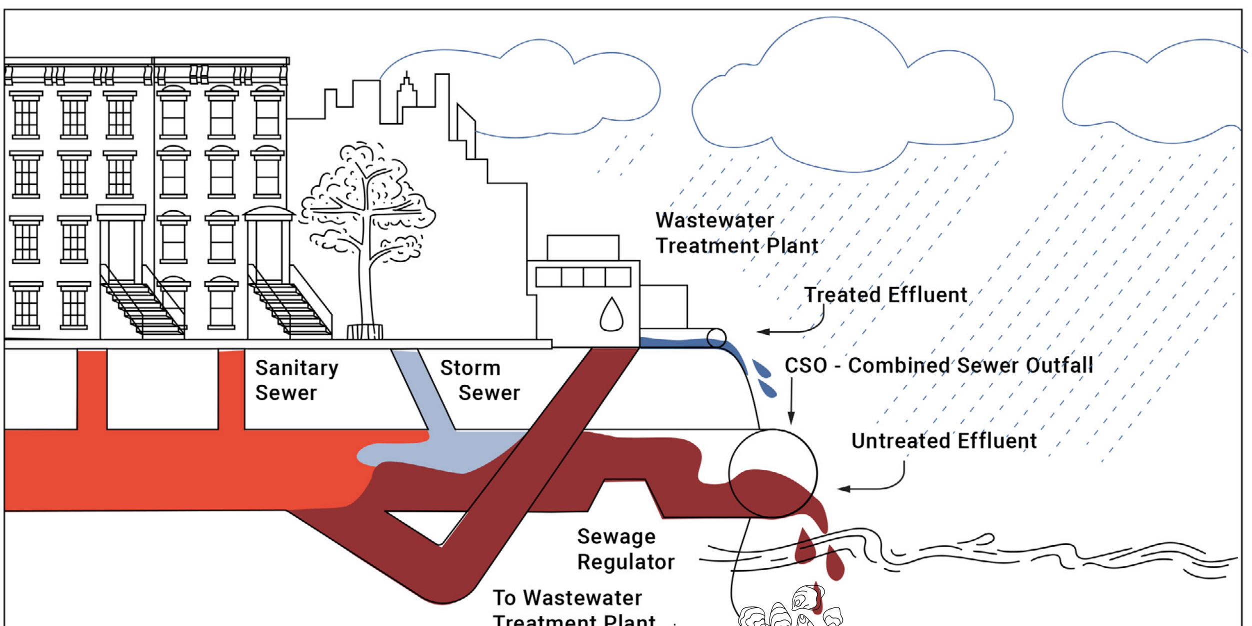

Wastewater Treatment Plant
Treated Effluent
Sanitary Sewer
Storm Sewer
Untreated Effluent
Separate Sewage System - Wet Weather
NY Harbor


Key
Storm Water
Sewage
Combined Sewage and Water

NAME ______________________________ DATE ______________________



Combined Sewage System - Dry Weather



Combined Sewage System - Wet Weather

Key

(light blue)	**Storm Water**
(red)	**Sewage**
(dark red)	**Combined Sewage and Water**

NAME ______________________________ DATE ______________________

Sanitary . . . Sewer?

1. What does the New York City Department of Sanitation do?

2. Sanitary napkin -- what is it?

3. What would you think of, if you heard someone talking about an "unsanitary napkin"?

4. Look at the words on the next page. Do you think all those words for "health" come from the same roots? Why or why not? Do some of the words seem more closely connected than others?

5. In English, what do you think the word "sanitary" usually means? (Hint: it's not exactly the same thing as health)

NAME ______________________ DATE ______________________

Sanitary . . . Sewer?

6. Could it have something to do with health? Always? Sometimes? Never? Can you give an example?

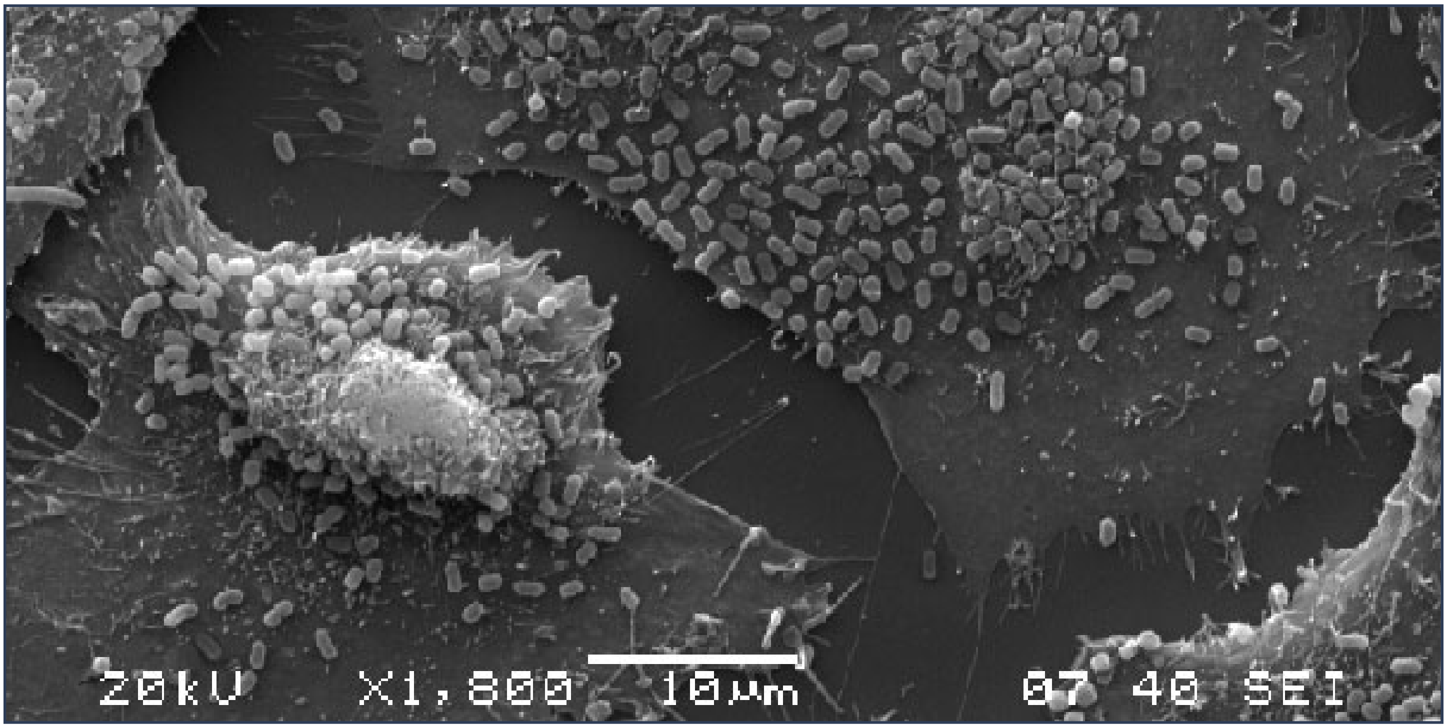
7. What is a sewer?

8. What could possibly be the meaning of a "sanitary sewer"? Take your best guess!

Word that translates as "health"	Language
Salut	Catalan
Santé	French
Sante	Haitian Creole
Salute	Italian
Salutem	Latin
Helse	Norwegian
Saúde	Portuguese
Sănătate	Romanian
Salud	Spanish
Hälsa	Swedish

NAME ______________________ DATE ______________________

What's in Poop?



- From the Institute of Food Research "Gut Health and Food Safety Image of the Month."
- Caption: "Scanning electron microscopy image showing attachment of pathogenic E. coli to human epithelial cells."
- Picture by Steven Lewis (Research group Dr Stephanie Schuller, Lecturer in Infection and Immunity at the Norwich Medical School at UEA and visiting scientist at IFR).

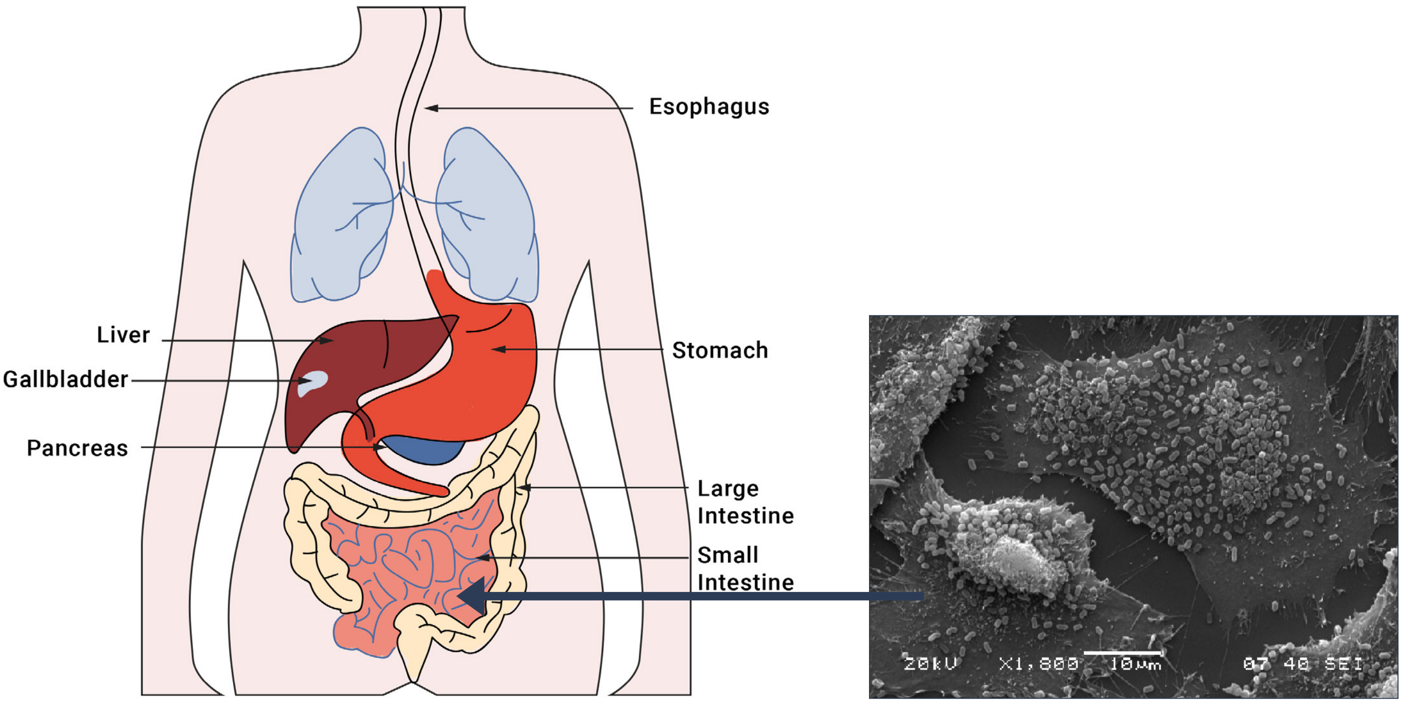
1. What do you notice in this picture?

2. This is a magnified image taken with a scanning electron microscope. Find something in this picture that gives us an idea of the actual size.

3. What shapes do you notice? Does anything look familiar?

NAME ______________________ DATE ______________________

What's in Poop?



4. Based on this human digestive system diagram, our CSO model and the CSO Diagram we looked at, how do you think harmful bacteria gets from a person's small intestine into New York Harbor?

5. How might sewage and bacteria in New York Harbor make it more difficult to restore oysters and increase the biodiversity here?

NAME ______________________ DATE ______________________

CSO Solutions

1. How could you reduce the pollutants in the sanitary sewer?

2. How could you reduce the pollutants entering the storm sewer?

3. How could you reduce the amount of water and pollutants coming out of the CSO?

4. What are some larger scale actions that could reduce the amount of pollutants affecting the sewershed?

5. What types of interventions could be designed and built that would help prevent pollutants from entering New York Harbor?

NAME ______________________ DATE ______________________

CSO Solutions

6. Sketch one of your designs (from question 5) and use labels.

NAME ______________________ DATE ______________________

CSO Solutions

7. If you build and test your design, describe the results here.

8. How would you improve your design to make it more effective?