New England Aquarium
Educational Activity Series

New England Aquarium

Protecting the blue planet

Engineering Ocean Currents

Learning Level
Intermediate: grades 5 – 8

Subject Areas
Science (Earth and Marine Science), Engineering, Design, Art, Literacy

Preparation
This activity is designed to stand on its own, but students may benefit from a prior exposure to terms such as ocean currents, adaptations, and plankton.

Duration of Lesson
This activity will require one to two class periods.

Lesson Standards
Next Generation Science Standards (NGSS):

- ETS1 Engineering Design
- MS-ETS1-4 Engineering Design
- MS-ESS2-6 Earth's Systems – Ocean Circulation

Supports Massachusetts Revised Science and Technology/Engineering (MA STE) Standards

Engineering Ocean Currents is a fun and interactive activity that is designed to enhance student understanding of the engineering design process. During this activity students learn about **plankton**, a vital group of aquatic organisms, and methods they employ to maintain their location near the surface of the ocean. Students will use what they learn about plankton to design a model of better energy generators to harness ocean current energy.

This activity was developed by the New England Aquarium with the support of National Grid. It's designed to align with the NGSS Standards (in support of MA STE) for grades 5 through 8 but can easily be adjusted to fit older or younger groups of students. The activity is designed to be self-contained, but pieces of it may be used as teachers see fit.

Objectives
The objective of this lesson is to give students hands-on time with the engineering design process. They will also learn to use knowledge of animal adaptations and natural systems to design solutions to engineering problems that humans face.

Students will understand:
- The engineering design process
- Ocean currents
- Buoyancy
- Locomotive adaptations of planktonic organisms

Students will be able to:
- Examine maps
- Draw and label an engineering design solution plan
- Complete the steps of the engineering design process
- Construct a neutrally buoyant object by identifying appropriate materials
- Communicate the results of their engineering solution to their peers.

Skills
Thinking critically and creatively, observing, drawing plans, labeling scientifically, experimenting, writing descriptively, building science literacy.

Vocabulary
See last page for full glossary

Background Information
Ocean currents are incredibly important to the flow of energy around our planet. As they circumvent the ocean basins, they regulate climate and move nutrients and life (like plankton) from one place to another around the planet. Learning about the adaptations that help plankton live in these currents may help us to make better machines to harvest some of this abundant energy.

Materials

- Transparent containers filled with water (used to test the buoyancy of students' designs)
- A variety of recycled materials that students can use to design their plankton-inspired current generators. Some examples include:
  - modeling clay
  - foil
  - straws
  - pipe cleaners
  - tooth picks
  - paper clips
  - Styrofoam
  - corks

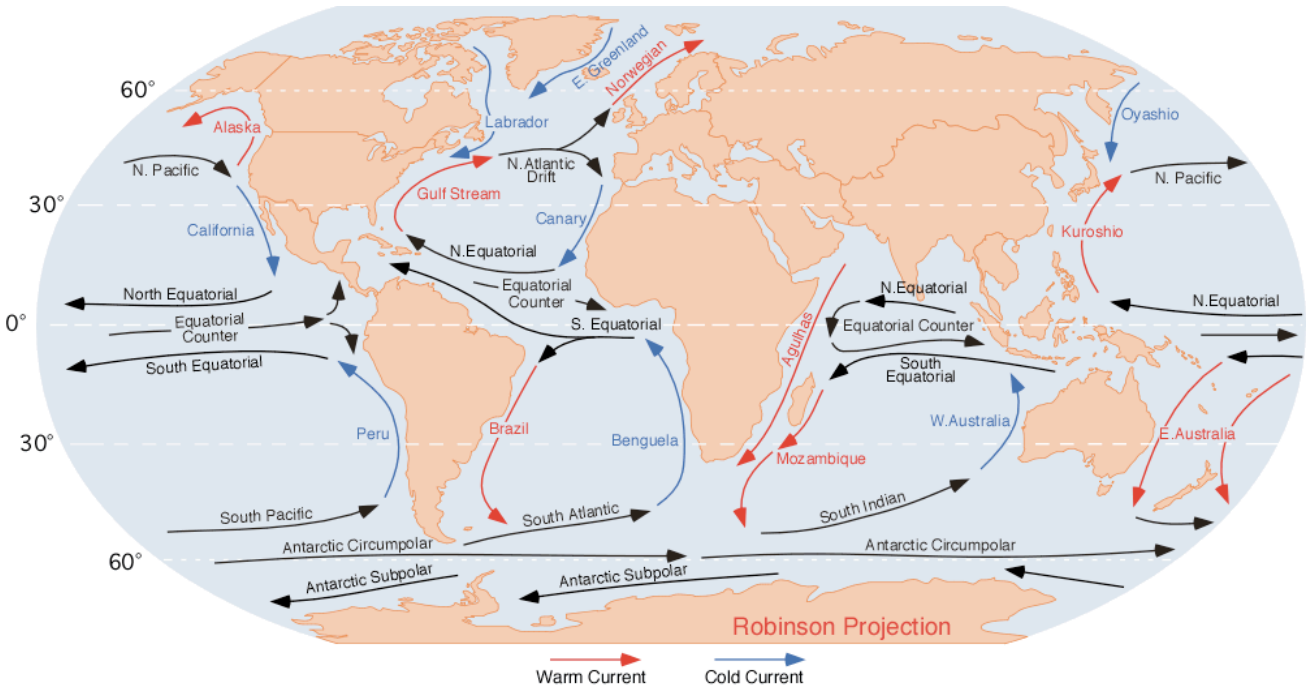
Procedure

PART 1: Introduction to Ocean Currents and Ocean Current Energy

A. Ocean Currents

Students will understand how surface ocean currents work, what drives them, and where in the ocean they are found.

1. Inform students that a surface **ocean current** is the movement of water driven by the wind, tide, ocean, water density (differences in temperature and/or differences in salinity), and Earth's rotation.
2. Explain that the map below (seen on their handouts located at the end of this document) shows the major surface ocean currents.
3. Give students some time to examine handouts of the map below.
   - What do they notice?
   - Are there any patterns?
   - What could be causing the patterns?
3. Review their observations and make sure to reiterate that the map shows major surface ocean currents, their direction, and their temperature (warm water in red and cold water in blue).



Earth with Surface Ocean Currents:
(http://www.physicalgeography.net/fundamentals/images/oceancurrents.gif)

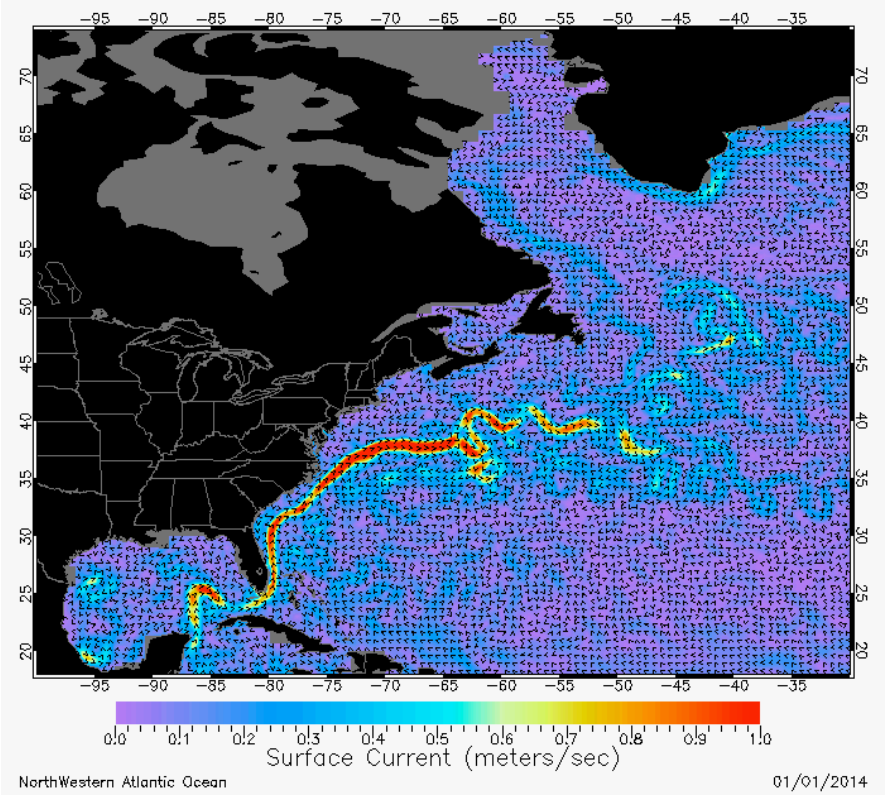
DIVING DEEPER—Examine how water chemistry drives ocean currents:
Discuss Deep Water (**Thermohaline Ocean Currents**) and complete experiments with water density (supported by New England Aquarium's Water Properties Outreach Class **www.neaq.org/schooling**). Contact the Teacher Resource Center at 617-973-6590 or trc@neaq.org for water density activities and experiments.

B. Ocean Current Energy Generators

1. Inform students that surface ocean currents flow more steadily than wind and carry more energy even though they travel at lower speeds. Have students think about their time outside. Does the wind always blow in the same direction and move all the time? Ocean currents are very steady and may change directions or speed slightly but tend to keep circulating for hundreds of years.

2. Ask the students if they can name any ocean currents.

3. Show the students attached image (image 2), also depicted below, and ask them:
   - What do they notice about the image?
   - Where is it?
   - What could it be showing?



Northwestern Atlantic Ocean Surface Current Speed:
(http://oceanmotion.org/html/resources/oscar.htm)

4. Inform them that it's an image of the eastern coast of North America and southern tip of Greenland, shown here in black. The rest of the image is made up of the North Atlantic Ocean. Ocean current speed is shown in colors ranging from purple to red. In this case purple depicts slow moving water and the red sections display fast moving ocean currents.

   - Where is the ocean current on the map?
   - Does anyone know the name of this current?

5. Tell students that the current is the Gulf Stream and that it's well known to residents of the eastern United States. It can be seen moving up the coast in red.

6. **Option One:** Have students work in groups with the attached map ("Northwestern Atlantic Ocean Surface Current Speed").

   Have students label what they know and work toward answering similar questions including:
   - What areas seem to lack ocean currents?
   - What areas have the strongest ocean currents?
   - In what areas would it be the best for the United States to install machines for ocean current energy generation? Why?

   Option Two: Have the students think like engineers.

   Present and discuss the questions below with the class:
   - What areas would be the best for the United States to install machines for ocean current energy generation?
   - Why do you think this is the case?

7. Review that the most cost effective locations for engineers to install ocean current energy generators are places where ocean currents are strong and close to land.

DIVING DEEPER—Explore ocean currents around planet Earth using this website:
http://earth.nullschool.net/#current/ocean/surface/currents/orthographic=-90.63,18.05,541

C. Making Energy from Ocean Currents

1. Inform students that since we've established that there are strong ocean currents that travel near the coast of the United States, we need to figure out how to construct a machine to harvest this energy. Many of these machines are tethered to the bottom and generate electricity as water from ocean currents moves through or past them. It's ideal to construct generators that remain below the surface, where currents tend to be the strongest and generators have a lower likelihood of impacting animals

2. **Optional Additional Activity:** Read and discuss articles about ocean current energy:

Case Study Articles:	
Japan Building Underwater Kites	**http://motherboard.vice.com/read/japan-is-building-underwater-kites-to-harness-the-ocean-current-for-power**
BOEM: Types of Ocean Current Energy Generators	**http://www.boem.gov/Renewable-Energy-Program/Renewable-Energy-Guide/Ocean-Current-Energy.aspx**

PART 2: Plankton

A. Plankton

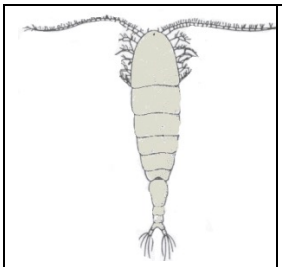
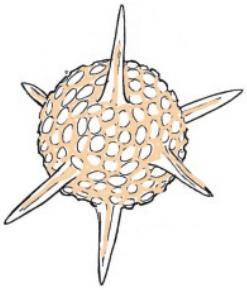
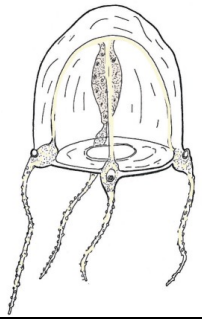
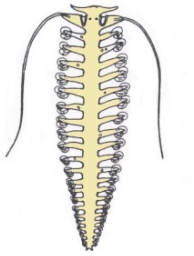
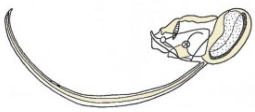
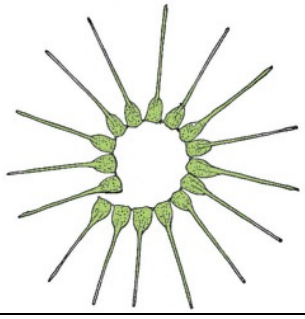
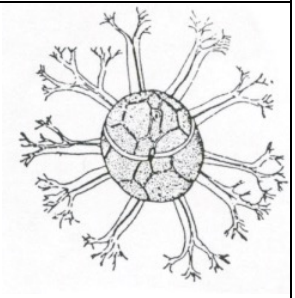
1. Ask students what types of things are carried around the planet by ocean currents? You may hear answers like animals, ships, plants, etc.

2. Inform students that ocean currents definitely do more than just move water and energy; they also carry many of the things they listed. Most notably they carry nutrients and **plankton**. **Plankton** are organisms that may be found drifting within the water column in both fresh water and salt water bodies. Although some plankton can swim, none are able to swim against ocean currents. Many types of plankton are small, like copepods, and some can be very large, like sea jellies. Some animals remain as plankton their entire lives, while others are plankton only when they're very young, like lobster, fish, and sea stars.

   Planktonic organisms have many adaptations to remain **neutrally buoyant** and stay within the flow of ocean currents. It's important that plankton stay within the flow of the ocean currents because that's where it finds its food source. Remaining **neutrally buoyant** is especially important for plantlike phytoplankton, which relies on sunlight to conduct photosynthesis

B. Plankton Adaptations

3. Have students examine attached sheets of plankton (some depicted below) and discuss what they notice about the organisms. What structures could help them remain neutrally buoyant?

			
Copepod	**Salp**	**Radiolaria**	**Medusa**
			
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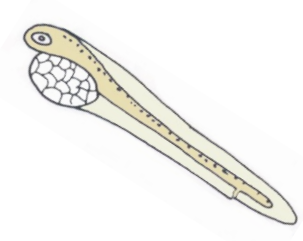
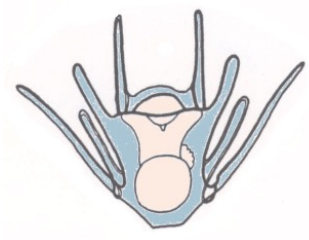
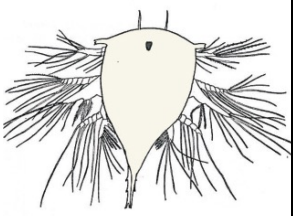
			
Thallasionema	**Fish Larvae**	**Echinoderm Larvae**	**Barnacle Larvae**

4. After discussing student observations, discuss that adaptations can be either structural, like the spines on their bodies that help them float, or behavioral, like some plankton's ability to weakly swim in the water (**locomotive strategy**). Some examples of adaptations include:
   - Cilia – tiny hair like appendages that wiggle in the water
   - Flagella – long tail-like appendage that plankton whips through the water
   - Spines – long protrusions from body
   - Overall shape – long or round
   - Actively moving – swimming, wiggling through water, using tail, legs, fins, or other appendages
5. To review and deepen understanding of planktonic adaptations, have students match structural and behavioral adaptations with individual species of plankton.

PART 3: Design Your Own Plankton Generator

Introduction:

1. Discuss that engineers sometimes look to nature to help them solve challenges they face when designing something. This growing field is called biomimicry.

   Like these engineers, we are going to learn from the adaptations of plankton to design a model of a machine that generates energy from ocean currents.
2. You will design and build your own plankton-inspired ocean current energy generator. Your ocean current energy generator must remain submerged (below the surface) and neutrally buoyant (floating within the water column) as long as possible.

Activity Outline:

1. Briefly frame activity described above.
2. Discuss the materials (possibilities listed in Materials section) students may use.
   NOTE: For younger groups, it's best to discuss how they expect each to behave in the water.
3. Have students look at images of common plankton (on attached sheets) to brainstorm ideas for their design.
4. Students should then draw a plan for their plankton inspired model for an ocean current energy generator. They should label the materials that they plan to use from those provided for them on their plan. (At this point, you may allow students hands-on time with materials as they draw to allow them get a better idea of what could work for their prototype).
5. Before students start to build their design, they must check in with a teacher. They should show their finished plan and their answers to the first two questions on the worksheet.
6. Students are then allowed to start building their model ocean current energy generator.
7. Have students finish their initial design before testing it in the water container.
8. Give students time to continue to improve their design.

This may be done with defined sections of "dry" building time followed by a water test, or as a continuous section of free building/testing time.

We find it works best to allow students to continue to alter and test their model with access to a water bin. They are able to troubleshoot and fine-tune their model

Make sure that students record each modification they make to their design, including why they made each change. This is an incredibly important step in the engineering design and experiment process.

PART 4: Wrap Up

Have students present their designs and experiences with the experiment, which gives them a chance to practice their oral presentation skills.

Possible questions for discussion:

- How would their designs work as a platform for generating energy from ocean currents?
- What modifications would they need to make?
- Engineers need to look at the pros and cons for each method of energy generation. Can they see any other issues with generating energy this way?

Optional Additions:

Dive further into Biomimicry

- Examine other examples of marine biomimicry.
- Examine Marine Foodwebs illustrating the importance of plankton.

Engineering Currents
Glossary

Engineering Design Process
Series of steps that an engineer uses to create a solution to something

Engineer
Someone who designs and builds machines, systems, and/or structures

Turbine
An engine that has blades that spin because of from pressure of water, steam, or air

Plankton
Organisms that drift or swim weakly in a body of water

Buoyant
Able to float

Neutrally Buoyant
When an object is neither rising or sinking

Biomimicry
Method to find sustainable solutions by studying nature

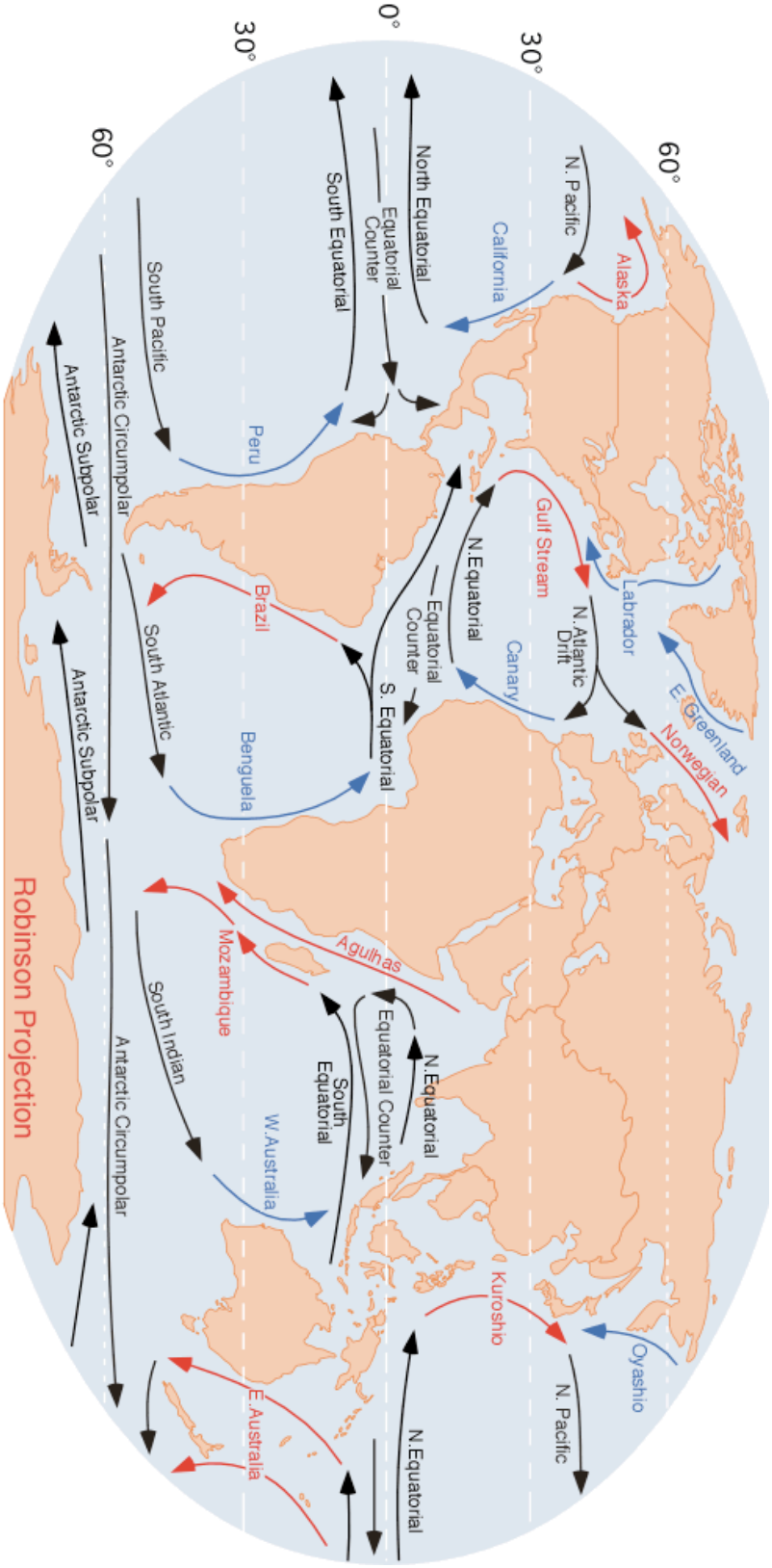
Locomotion
Movement or the ability to move

Behavioral Adaptation
An action that an organism does to survive

Structural Adaptation
Physical features of an organism

Engineering Currents

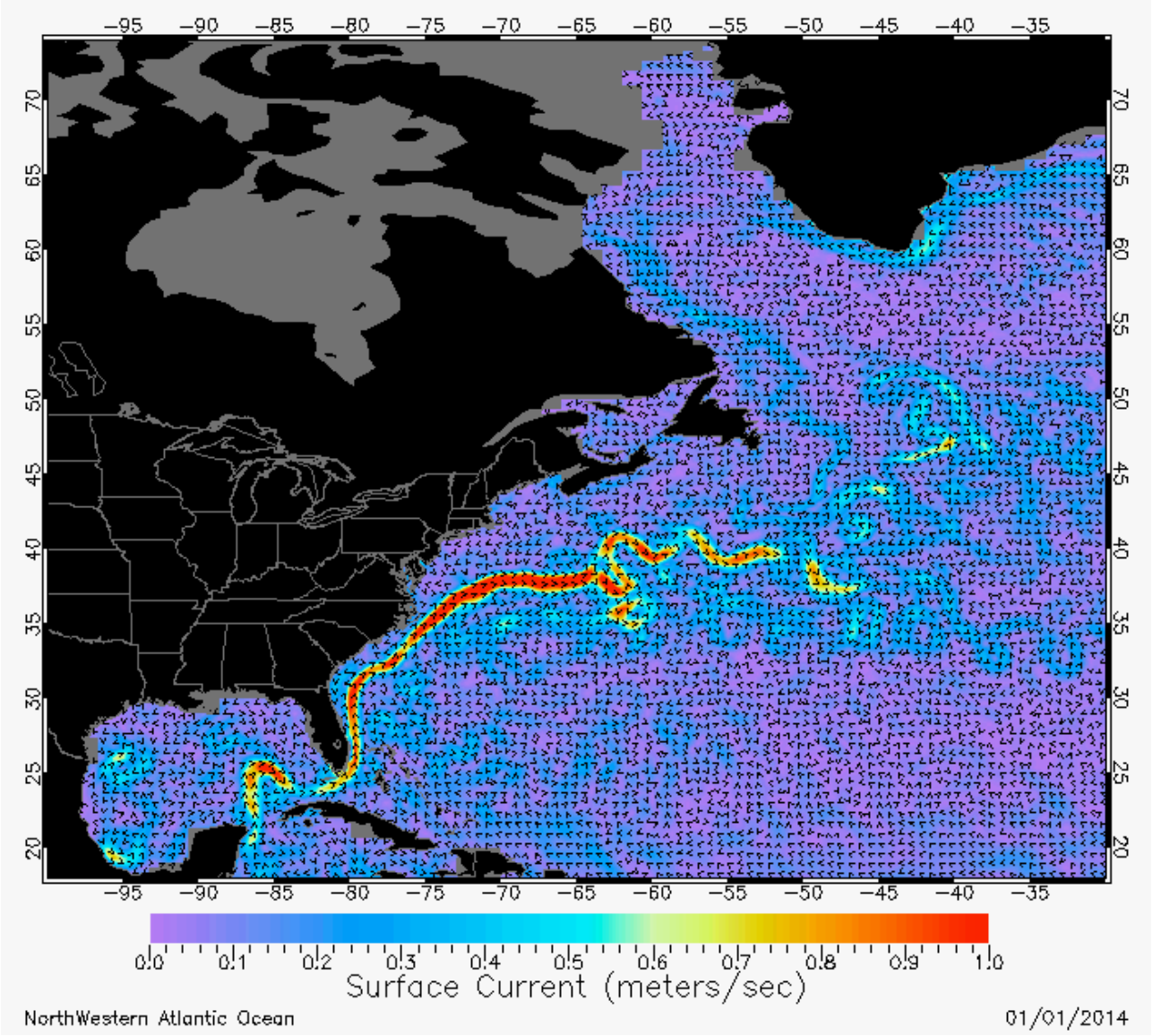
Ocean Currents Map



Earth with Surface Ocean Currents:
(http://www.physicalgeography.net/fundamentals/images/oceancurrents.gif)

Engineering Currents

Ocean Current Speed Map

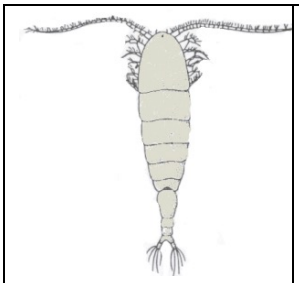
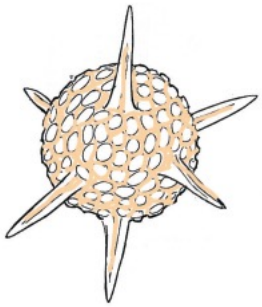
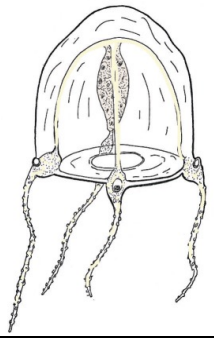


Northwestern Atlantic Ocean Surface Current Speed:

(http://oceanmotion.org/html/resources/oscar.htm)

Engineering Currents

Examples of Marine Plankton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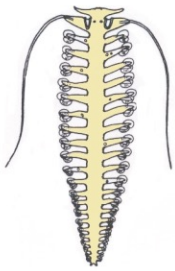	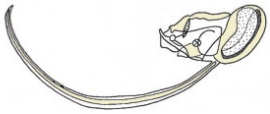	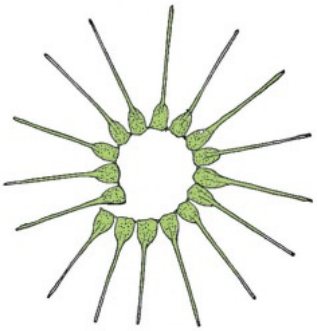	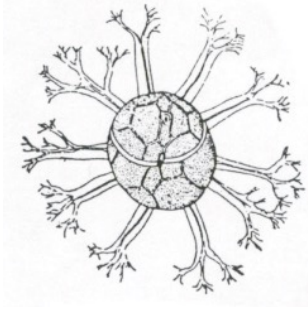
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	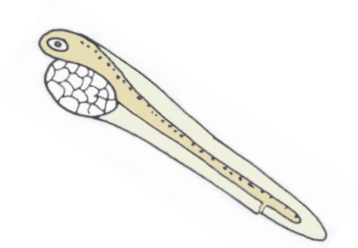	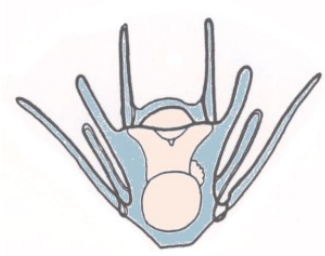	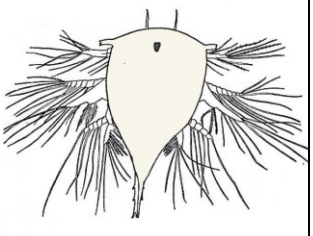
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Engineering Currents

Ocean Current Energy Generator Model

NAME

DATE

1. **Draw a picture of your design in the box below.**

What type of **plankton** inspired your model?

What are the key features that will make it **float**?

2. **Build and test your model.**

List the different modifications you made to your model in order to make it neutrally buoyant (float just under the surface of the water).

3. **Conclusion:**

Compare your model to the ones your classmates made. Which model floated best? Why?

What would you change about your design to make it float better next time?