22C Global Winds and Ocean Currents

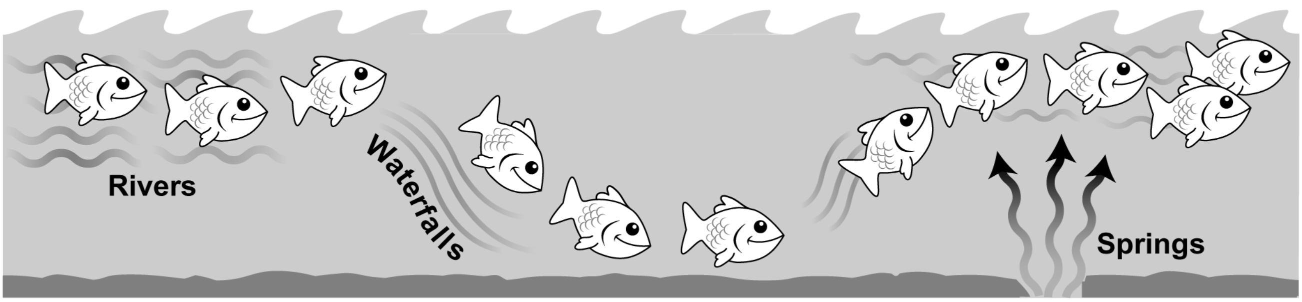
How do temperature and salinity cause ocean layering

Did you know that there are rivers in the ocean? In some places, there are two rivers running side-by-side—in opposite directions. Now imagine underwater waterfalls and underwater springs. All of these exist in the world's oceans as a result of differences in water temperature and *salinity* (saltiness). How do temperature and salinity differences cause these underwater rivers, waterfalls, and springs? *Density* changes are the key. In this investigation, you will discover how temperature and salinity create currents, underwater waterfalls, and springs in the ocean.

Materials

- A clear plastic cup
- Two foam coffee cups
- Eyedropper
- Pipette with a barrel longer than an eyedropper's
- Salt
- Measuring spoon—teaspoon size
- 10 cm square of single ply cardboard
- Pencil
- Scissors
- 20 staples
- Newspapers
- Cafeteria tray or paper plate
- Source of hot and cold water
- Food coloring: red, green, and blue

The ocean contains:



1 Density and ocean currents

As global winds push ocean currents around the planet, the ocean water undergoes several changes. As the current moves nearer to the equator, the water warms up. As it moves toward the poles, the water cools down. These changes affect the density of ocean water.

When the current moves through a warm area, there is an increase in evaporation. Since evaporation removes fresh water and leaves salt behind, the salinity of the current increases. This increases the current's density. Fresh water is added back to the ocean through melting ice, rivers, and rain. Adding fresh water to the salty ocean water decreases its density.

These changes in density cause ocean currents to float and sink at different points in their journeys. In this investigation, you will model underwater rivers, waterfalls, and springs. Then you will use your observations to help you understand the movements of the Atlantic gyre, an ocean current system. You will also discover how these density differences play an enormous role in the life of the world's most important fishing grounds.

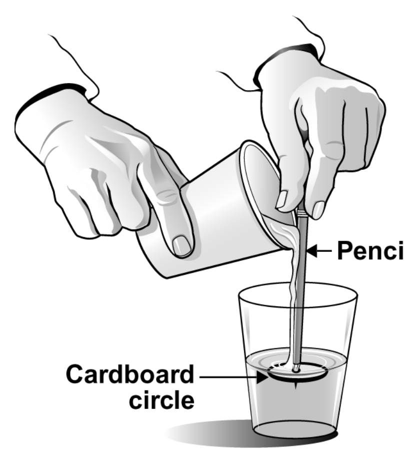
a. Which do you think is more dense: warm or cold ocean water? Why?

b. Explain why dissolved salt increases the density of ocean water.

2 Observing salinity-dependent layering

This investigation requires care and preparation to keep your cleanup quick and easy. Spread newspaper over your work area to catch drips. Keep any water-filled cups over a tray or paper plate. Wipe up any spills before they get tracked around. Discard any water in the bucket provided or in the sink.

1. Make a pouring stick by cutting a cardboard circle about 4 centimeters in diameter with your scissors. Press the point of a pencil into the center of the disk so that it is stuck firmly onto the pencil.
2. Fill a clear plastic cup half-full with cool water. Add 1 teaspoon of salt to the water. Add 2 drops of green food coloring. Stir until the salt dissolves.
3. Fill a foam cup half-full with cool water.
4. Have a team member hold the pouring stick at its top, near the eraser. Lower the pouring stick into the middle of the clear cup so that the cardboard disk is just under the surface of the green water. Have a second team member hold the lip of the foam cup up to the pouring stick.



5. Tip the foam cup so that the cool water flows slowly down the pouring stick. The first team member must move the pouring stick upward as the second team member pours so that the cardboard disk remains at the surface of the water. Continue to add water until the clear cup is almost full, and then gently remove the pouring stick. You have created two ocean layers, separated by their salinity.

a. Try slightly tipping the clear plastic cup. Are the layers stable? Do they resist mixing?

b. Tear off a small piece of foam cup. Press some staples into the foam, and place it on the surface of the clear water. Remove the foam and add more staples to it, one at a time, until the foam bit sinks. Where did the foam bit end up? Why?

c. Explain why the clear water floats over the saline water.

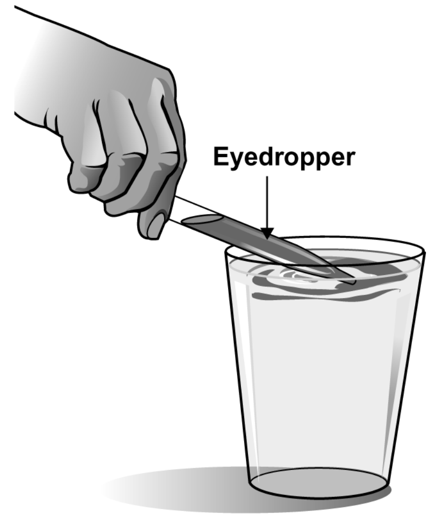
3 Exploring temperature-dependent layering

1. Fill a clear plastic cup half-full with cool water. Add 2 drops of blue food coloring. Stir to mix.
2. Fill a foam cup almost full from the hot-water source. Add 2 drops of red food coloring. Stir to mix.
3. Add hot red water to the clear cup using the pouring stick as you did in salinity-dependent layering. You have again created two ocean layers, this time separated by their temperatures.

a. Try tipping the cup slightly. Are the layers stable? Do they resist mixing?

b. Explain why the hot red water floats over the cool blue water.

4 Creating an underwater waterfall



1. Fill a clear plastic cup nearly full with cool water.
2. Fill a foam cup half-full with hot water. Add a pinch of salt. Add 6 drops of red food coloring. Stir until the salt dissolves.
3. Place the eyedropper into the hot red water to warm it up. After a minute, fill the dropper barrel with the water.
4. Hold the dropper so that it lies at a flat angle at the surface of the clear water with the tip just under the surface. Gently squeeze out a layer of hot red water onto the surface of the clear water.
5. After a short cooling time, the red layer will form little waterfalls that sink through the clear water. They may even form little smoke-ring-like structures as they fall. If this does not happen within a few minutes, add a little more salt to the hot red water, stir, and try again.

a. Explain why the red water floats at first.

b. Explain why the red water eventually sinks.

5 Observing underwater springs

1. Fill a clear cup three-quarters full with cool water. Add a heaping teaspoon of salt to the water. Stir until the salt dissolves.
2. Fill a foam cup half-full with cool water. Add 6 drops of blue food coloring. Stir to mix.
3. Fill the eyedropper with cool blue water.
4. Gently lower the dropper into the salt water so that the tip is near the bottom. Gently squeeze the dropper so that a small stream of blue water is released.

a. Where did the blue water go? Why?

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b. In this model, the blue water was less salty than the surrounding water. Think of another difference you could use to create an underwater spring. Write your own procedure, test it, and explain what happened.

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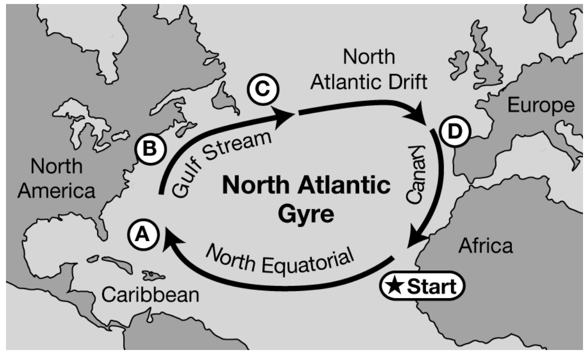
6 Applying your knowledge

You can use these experiments to understand the North Atlantic gyre, a system of currents that occupies the North Atlantic Ocean basin. After each description, fill in the experiment that applies (salinity-dependent layering, temperature-depending layering, underwater waterfall, or underwater springs), and then determine whether the current will float or sink.

We will start with the part of the North Atlantic gyre off the coast of Africa. We will assume that the temperature of the water is cool and its salinity is low. The low salinity is dominant and the current is floating on the surface.



a. From there, the North Equatorial Current flows westward toward the Caribbean Sea. Then it turns north and becomes the beginning of the Gulf Steam. During this trip along the equator, the intense sun warms the current and evaporates a lot of water. This makes the water both warm and highly saline. The high temperature is dominant.

Experiment: ______________________ Float or sink: ______________________

b. After turning northward, the Gulf Stream flows along the United States' Atlantic Coast. The water is highly saline, but it remains warm. The high temperature remains dominant.

Experiment: ______________________ Float or sink: ______________________

c. As the Gulf Stream leaves the U.S. coast, evaporation is not as great in the cold northern regions, but the cooling effect is very significant. The low temperature is dominant.

Experiment: ______________________ Float or sink: ______________________

d. Now part of the Gulf Stream becomes the North Atlantic Drift. Fresh water from ice melt may mix with these cold waters off the coast of Europe. Lower salinity is dominant.

Experiment: ______________________ Float or sink: ______________________

7 Extension: Thermohaline currents and the ocean food chain

Back in the 1960s, it was popularly believed that the key to feeding the world was the bountiful harvest that could be taken from the seas. Today, we are faced with the collapse of fisheries on both sides of the Atlantic. Why has the ocean proven to be such a modest food source?

The food paradox of the oceans is based on the nutrient cycle. For new creatures to grow, the nutrients from the old creatures must be recycled. Unfortunately, when ocean creatures die, they take their nutrients to the deep bottom. The photosynthetic plankton (phytoplankton) that do the recycling must live in the sunlit top-600 feet of ocean, so recyclers and the needed nutrients are hopelessly separated by thousands of feet of ocean unless something can transport the nutrients to the surface.

a. Two of the biggest fisheries in the world are off the Canary Islands and Peru. Can you explain why?

b. If global climate change eliminates all ice from the poles, how might this affect ocean currents and world fisheries?