Jane Goodall Institute

Learning Resource

Warm seas, cold seas, ocean currents

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What makes one sea warm and another sea cold? What makes water flow from one part of the world to another? And how does this affect where we find life in the oceans of the world?

In this activity you and your students will:

- Carry out some simple experiments that explain the basics of ocean currents.
- Carry out some experiments that show the conditions plant life needs to thrive and how this relates to water temperature.
- Learn about the impact this has on the diversity and location of marine life.
- Create maps showing the major ocean currents and life 'hotspots'.

Objectives

To understand why water flows around the world and the effect this has on marine life.

What do I need to make it work?

There are a number of experiments in this activity.
You can choose to carry out all of them, a selected few or none at all depending on the amount of time and resources you have available – we've filmed or picked videos for each experiment to fill in for the ones you don't carry out yourself.

What things will my students create?

- Maps of ocean currents and ocean life.

Ocean life

This resource touches on where you find life in our oceans, but if you want to learn more about the particular plants and animals that thrive in warm and cold seas, then be sure to also try our 'Ocean life' resource.

Convection cells

Why are some parts of the Earth warmer than others? What effect does this have on the oceans?

Experiment 1: torch and ball

Watch this experiment (30 seconds): youtu.be/578cejRWHrQ

To carry out this experiment yourself, you will need:

- A small torch that can be focused on something fairly close
- A medium or large size ball, e.g. a child's football

Have one student hold the torch and another the ball. Turn on the torch and point it at the ball. Find a distance between torch and ball such that when the torch is focused on a spot on the ball's 'equator', the light only covers a small area. From the same distance, change the aim of the torch so that it is pointing at a higher 'latitude' on the ball. Note that the light now covers a much bigger area.

What does the experiment tell us?

Areas near the Earth's equator receive more of the sun's energy than areas near the poles.

The energy received from the sun is spread out over a much smaller area near the equator than it is nearer the poles. Areas on the Earth's surface like the equator that receive more energy per square metre get heated to a higher temperature than areas like the poles.

Experiment 2: temperature and salt

Watch this experiment (1 minute): youtu.be/ZXo6i6ts5EE

To carry out this experiment yourself, you will need:

- A clear glass vessel such as a beaker from the school science lab filled with water at room temperature
- A smaller container of hot water
- A smaller container of room-temperature salt water (the more salt the better)
- Red and blue food colouring
- A pipette

Add a small amount of red food colouring to the hot water and mix well. Add the blue food colouring to the salt water. Gently add a few drops of the hot water to the large beaker – it should float around at the top. Now add a few drops of the salt water – it should sink to the bottom of the beaker so that you have three distinct layers.

What does the experiment tell us?

Warm water is less dense than cold water, and saltier water is more dense than fresher water.

You can see from this experiment that we might expect the water near the surface of the ocean to be warmer and less salty than water near the bottom.

Experiment 3: convection cells

Watch this experiment (3 minutes): youtu.be/0mUU69ParFM

To carry out this experiment yourself, you will need:

- A small-medium sized clear plastic tank, like a fish tank, half filled with room temperature water. You should be able to safely balance the tank on two mugs
- 3 identical mugs, two filled with ice-cold water and one filled with hot water
- 2 coasters
- Red and blue food colouring (paste or gel is best).

Place the two mugs of cold water onto the coasters, and balance the tank on top of them (space them widely). Carefully place a blob of red colouring at the bottom of the tank, in the centre (you may need a pipette for this). Now place two blobs of blue colouring either side of the central blob (leave a reasonable gap between them).

Slide the mug of hot water under the centre of the tank, beneath the red blob. As the water in the tank is heated by the mug, you will be able to watch convection cells develop as the water rises near the middle, travels along the top to the edges of the tank, cools, and returns to the centre along the bottom.

What does the experiment tell us?

The density differences in the water caused by differential heating drive currents.

In experiment 1 we saw that the Earth receives much more heat energy from the sun at the equator – this is equivalent to the mug of hot water under the centre of the tank. The mugs of cold water at the edges represent the Earth's poles. Experiment 2 showed us that warm water is less dense than cold water. This experiment shows us that these two effects combined cause currents in the 'ocean' represented by the water in the tank.

Coriolis effect

The results of our experiments show that we might expect ocean water to be heated near the equator, travel outwards from there towards the poles along the surface where it cools and sinks, being pulled back towards the equator nearer the bottom of the ocean. And that indeed is what happens, but there is something else going on as well: the coriolis effect.

The coriolis effect is the name given to the way things which are travelling in a straight line appear to have a curved path when viewed from a rotating frame of reference such as the surface of the Earth.

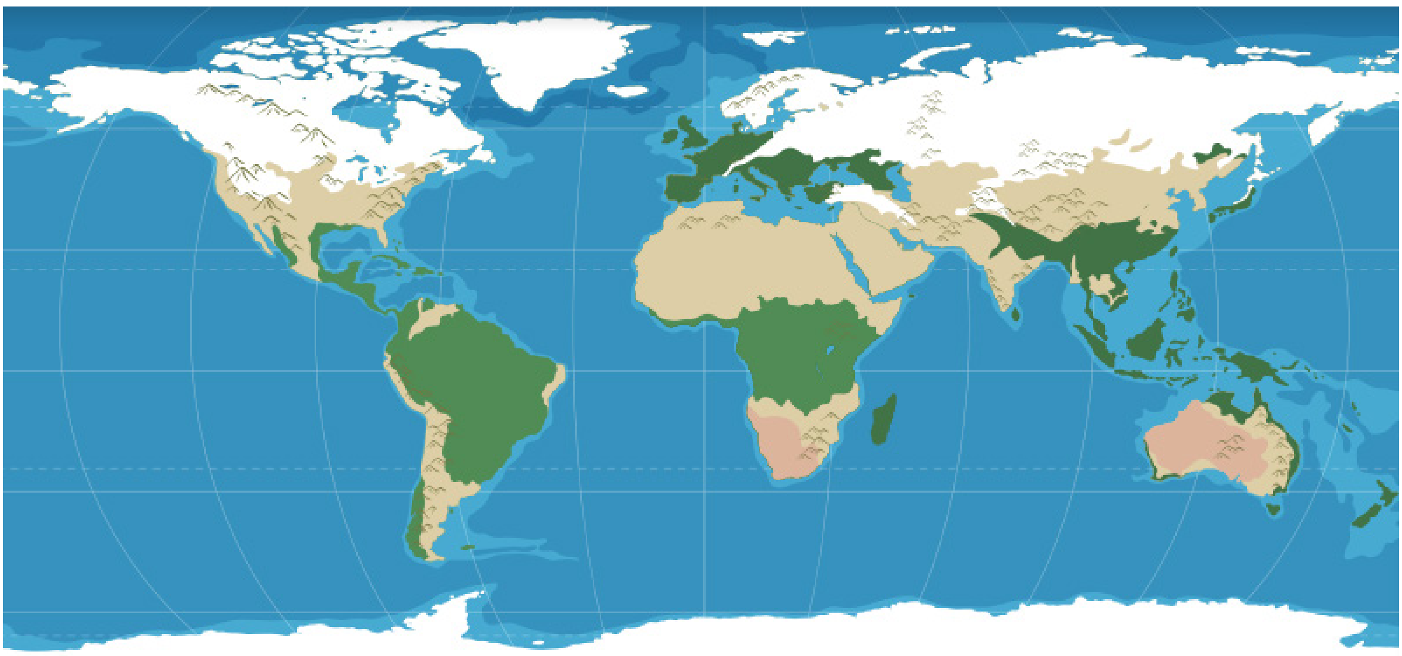
With care, it is possible to demonstrate the coriolis effect using a ball and a merry-go-round, but you may prefer to just watch the video for this one: youtu.be/mPsLanVS1Q8.

Mapping the main ocean currents

We now have everything we need to predict how we might expect the main ocean currents to travel around the Earth's oceans.

Older students: Ask them to try and draw what they think the main ocean currents might look like on a base map,using what they have learnt about convection cells and the coriolis effect, then compare to the map shown later.

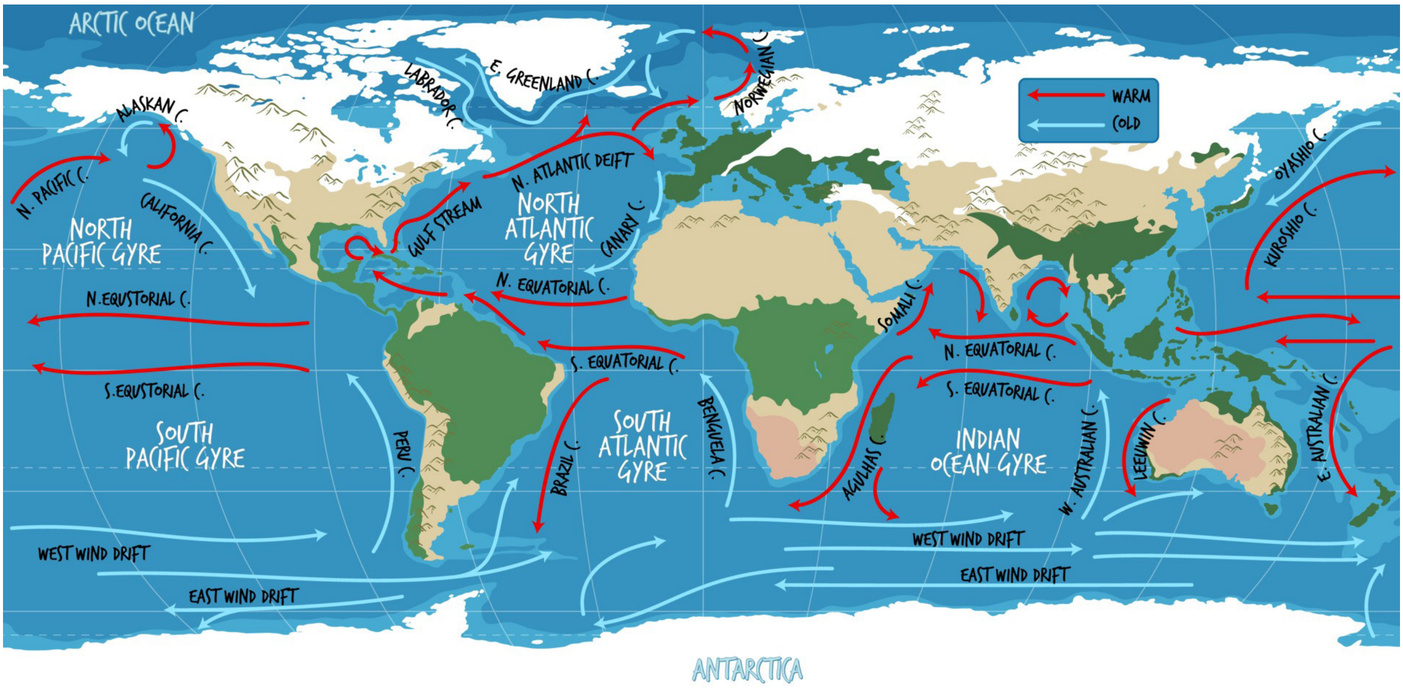
We recommend using a basemap like this one:



We've prepared a low-ink colour map for you to download and print: bit.ly/rs-globe-map

Younger students: Show them the ocean currents map below and relate what they can see back to convection currents and the coriolis effect. The differential heating/convection cell experiment helps explain the flow of warm water from the equator towards the poles, and the coriolis effect accounts for the circular patterns:

Download your own copy of the ocean currents map from Vecteezy: bit.ly/3x1nprD



Growing plants

Ocean currents can help us predict where we see the most life in our oceans, but we also need to know a few more things.

Experiment 4: what do plants need to grow?

Watch this experiment (5 minutes and 40 seconds): youtu.be/Nffg3GlSuXg

To carry out this experiment yourself, you will need:

- Some dried beans, such as pinto beans
- 6 glass jars, two of which need well-sealed lids (jars for preserving food work well)
- Some cotton wool balls
- Some soil
- Water

Fill four of the jars about halfway to the top with loosely-packed soil. Fill the remaining two jars to the same height with cotton wool. Add a few beans to each jar, placing them gently between the soil/cotton and the glass wall so that you can see them. They should be about a couple of centimetres below the surface of the soil/cotton. Add water to each of the jars so that the soil/cotton is damp but not soaking wet. Seal two of the jars containing soil tightly with the lids.

Place one set of three jars (cotton, soil with no lid, soil with lid) somewhere fairly sunny, and the other set in a cupboard where it is dark. Leave them for a week, checking that the soil/cotton wool in the open jars is damp every day and adding water if required (try not to open the sealed jars unless you can see that the soil is getting very dry).

After a week, compare how well the beans have grown in each of the six jars. What can this tell us about which of the sun, nutrients (soil) and air are needed for healthy plant growth?

What does the experiment tell us?

As well as water, plants need access to sunlight, nutrients and air to grow well.

The beans in the open, soil jar that was kept in the sunlight should have produced the healthiest, most vigorous growth.

Experiment 5: air

We learned from experiment 4 that plants need water, sunlight, nutrients and air to grow. As we are looking at life in the oceans, access to water is not a problem.

Sunlight in the oceans

The sun can penetrate approximately the top 200m of the ocean, known as the sunlit, or photic zone. Below that we find the twilight zone then the midnight zone. Learn more: youtu.be/uKhpx6lAH1k

Sunlight, too, is plentiful in the upper part of the oceans. Nutrients in the ocean are mostly derived from organic matter on land making its way into the sea, so you tend to find the most nutrients in the parts of the ocean which are nearest the land. So what about air?

Watch this experiment (2 minutes): youtu.be/wQanYgXZtQg

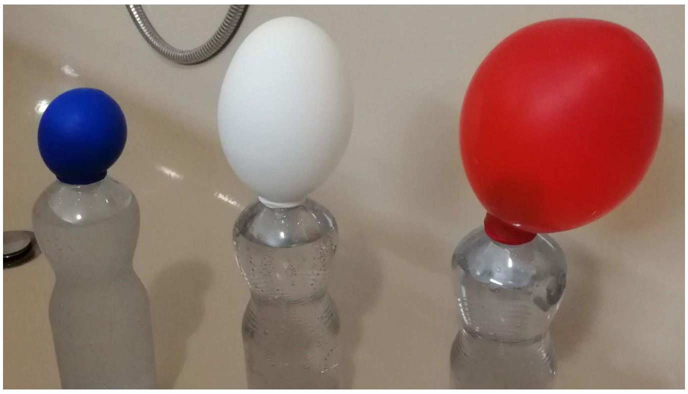
To carry out this experiment yourself, you will need:

- 3 small PET bottles of carbonated (fizzy) water with screw lids
- Some uninflated balloons (you need one per bottle, plus some spare)
- A large container of very hot (but not boiling) water, such as a large saucepan
- Access to a fridge or freezer
- Somewhere to open the bottles where it does not matter if they spill

Carefully stretch a balloon over the top of each closed water bottle. Work the neck of each balloon down so that the lid of the bottle is completely within the bulb. Place one bottle in the fridge for a few hours (or in the freezer for around 30 minutes, be careful not to let it freeze). 30 minutes before you are ready to take the cold bottle out of the fridge/freezer, submerge a second bottle in the container of hot water and leave it for 30 minutes. Keep the third bottle at room temperature, out of direct sunlight.

You should now have one bottle containing fizzy water at around 10°C, one with water at around 20°C and one with water at around 40°C. Place the bottles somewhere where it does not matter if they spill and carefully unscrew the lid of each bottle, keeping it within the balloon.

As the gas within the bottle escapes, it will fill the balloons. Note how the cold bottle releases relatively little gas, and the hot bottle releases much more.



Here's our attempt! The cold bottle is on the left with the blue balloon, the room temperature bottle is in the centre and the hot bottle is on the right with the red balloon.

What does the experiment tell us?

Different temperatures of water are able to hold different amounts of dissolved gas.

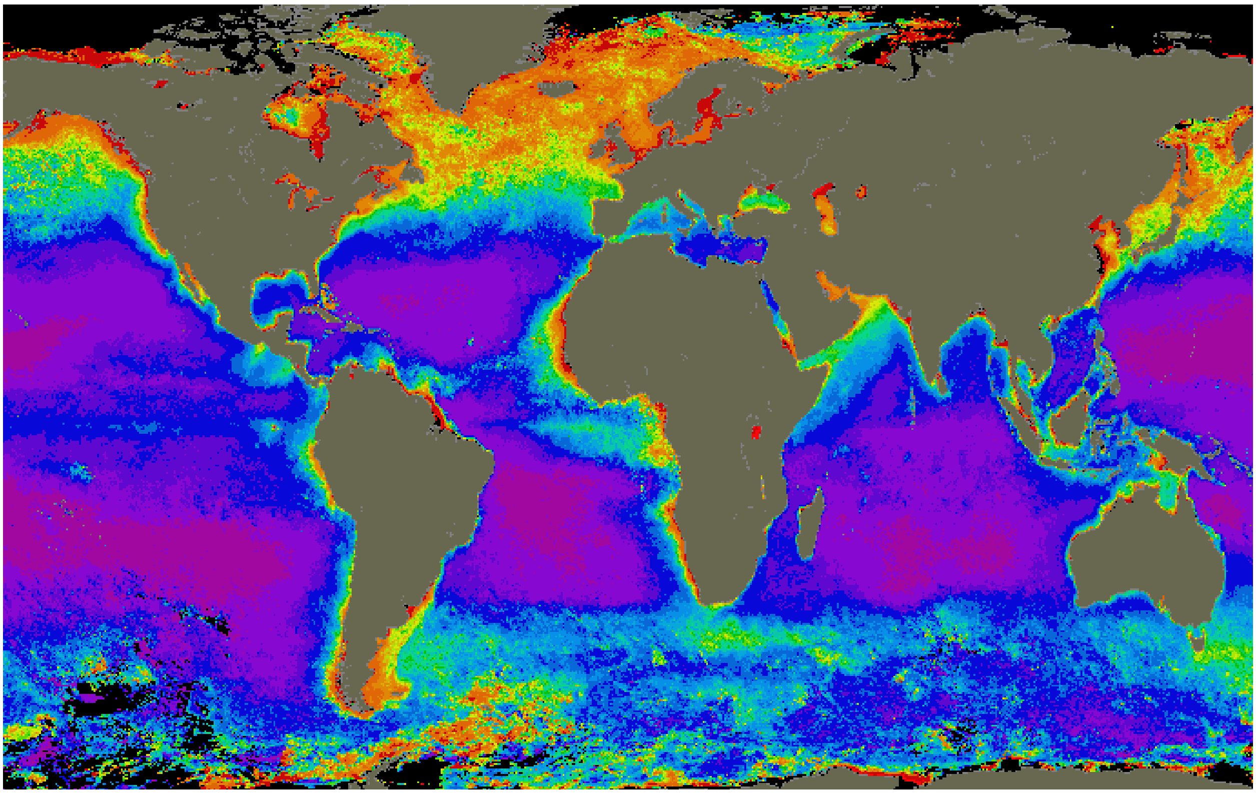
Assuming that each bottle started off containing the same amount of dissolved gases, the experiment shows that hot water can contain less dissolved gas than cold water (as more gas is expelled into the balloon from the hot water bottle).

Mapping ocean life

We now have everything we need to predict where we might find the most plant life in the oceans. And since animals need something to eat, this is also a great predictor of where we find the most animals too.

Older students: Ask them to try and draw what they think the most life can be found in the oceans, then compare to the map shown later. We can assume that everywhere on the ocean surface has a good supply of sunlight and water, so think about where in the oceans you can find the most nutrients, and the most dissolved gases.

Younger students: Show them the map below and relate what they can see back to the ocean currents map, the arrangement of the continents and hence where we find the most nutrients and the most dissolved gases.



Red and orange indicate high concentrations of phytoplankton. Concentrations decrease as you go down the colour spectrum. Image from NASA's SeaWiFS mission. Downloaded from bit.ly/3PRD2t6

The map above shows the global distribution of photosynthetic algae called phytoplankton. Red and orange show the highest concentrations, decreasing through the colour spectrum. You can see that the most phytoplankton is found in high latitudes where the water is cold (hence containing more dissolved gas) and near land (which provides nutrients). There is also an increase in concentration around the equator – thinking back to our ocean currents pattern and the convection cell experiment, this is where relatively cold, gas rich water which sank at the poles is moving up from near the bottom of the ocean towards the surface.

Biodiversity

This resource has focused on working out where in the oceans we can see the most life. So if the most life is in the colder oceans, why do we always think of tropical oceans as being teeming with life? There are a couple of reasons:

Firstly, because there are fewer nutrients to be found in tropical seas, life tends to concentrate in the areas where they can be found. So, the productive areas of a tropical ocean tend to be ***very*** productive, with lots of life crammed into a relatively small space. In the colder oceans things tend to be more spread out.

Second, although the overall number of plants and animals is greater in colder seas, the ***diversity*** of life is greater in tropical seas. Seeing lots of variety can trick us into thinking that the overall number of animals we see is higher than it actually is.

Taking it further

Although the ocean model we built using these experiments is very simple, it does a good job of explaining the basics of ocean currents and how they affect the distribution of life. In reality the picture is more complex – in particular, circulation of air in the atmosphere helps drive the surface flow of water in the oceans, and the density changes that help drive the deep circulation are influenced by salt content as well as temperature differences. A good starting point for gaining a full understanding is chapter 9 of the freely available book “Introduction to Oceanography” by Paul Webb, which can be found online at https://rwu.pressbooks.pub/webboceanography/

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