8TH GRADE

TEACHER RESOURCE GUIDE

THEME: Temperature, salinity, and density are three dynamic, interconnected, and important characteristics of water.

CRITICAL ISSUE: Climate Change

CONTENTS:

Aquarium of the Bay
a division of bay.org

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MISSION STATEMENT:

Aquarium of the Bay's Education and Conservation Department's mission is to promote literacy in ocean and watershed health, climate change issues, and science career development through the lens of critical issues such as sustainable seafood, marine protected areas, marine debris and plastics, climate change and fresh water flows.

ACKNOWLEDGEMENTS:

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S. D. BECHTEL, JR. FOUNDATION
STEPHEN BECHTEL FUND

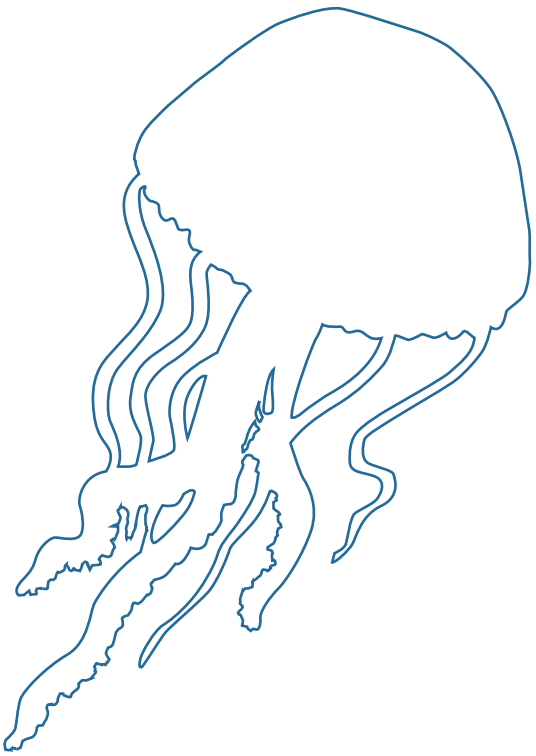
LESSON 1

TEMPERATURE AND SALINITY INVESTIGATION

Enduring Understanding: The temperature and salinity of water impact its density.

Materials

- Water
- Salt
- Food coloring or other dye (at least four colors)
- Refrigerator
- Microwave (optional)
- Beakers or cups
- "Temperature and Salinity Investigation" data sheets



SETUP:

1. Make copies of "Temperature and Salinity Investigation" data sheets.
2. Collect four batches of water (large enough for each group to get a sample of about six to eight ounces of each kind).
3. Prepare each batch differently, as outlined below:
   - Mix two batches with salt until fully saturated, creating saltwater. You want to make them as saline as possible to exaggerate the effects of salinity on density.
4. Chill one batch of saltwater in a refrigerator, preferably overnight but for at least two hours. (NOTE: If you are short on time, you may also chill it for a short period of time in a freezer. Remove before water freezes.)
5. Heat one batch of saltwater in the microwave until warm. (NOTE: If you do not have access to a microwave, you may add salt to warm tap water.)
   - Two batches are freshwater
6. Chill one batch of freshwater in a refrigerator, preferably overnight but for at least two hours. (NOTE: If you are short on time, you may also chill it for a short period of time in a freezer. Remove before water freezes.)
7. Heat one batch of freshwater in the microwave until warm. (NOTE: If you do not have access to a microwave, you may use warm tap water.)
   - In the end you should have cold saltwater, warm salt water, cold freshwater, and warm freshwater.
   - Dye each sample with a different shade of food coloring (NOTE: Add a small amount of food coloring. Too much food coloring will turn the water opaque, making it difficult for students to discern the line between layers.
   - Label each type of water appropriately.
8. Gather eight beakers or cups for each group you have: four for samples and four for layering.

SETUP CONTINUED:

9. Remove the chilled water from the refrigerator and warm the warmed water as close to the start of the lesson as you are able. If the chilled water must be out of the refrigerator for an extended period, add ice to keep it sufficiently cool.

PROGRAM OUTLINE:

Introduction

- Briefly discuss the concepts of temperature and salinity.
  - Temperature is a measure of heat, or the kinetic energy of the particles, within a given object. It is measured in degrees Celsius or Fahrenheit.
  - Salinity is the measure of the amount of dissolved salt in water. It is usually measured in parts per thousand (abbreviated ppt or ‰).
- Explain that students will be using four beakers (or cups) to layer two types of water together to see how water samples of different temperatures and salinities layer. They will only get four beakers, so they must carefully choose the combinations they layer.
- Explain that there are four different type of water: cold saltwater, warm saltwater, cold freshwater, and warm freshwater.
- The students' goal is to layer the different types of water and construct an argument using their trials as evidence for the effect of temperature and salinity on the way the water layers.
- Pass out data sheets for recording results.

Investigation

- Break the students into small groups to work on the investigation together. The goal is for the students to work out both the logistical and content aspects of the lesson on their own, without the teacher driving the instruction.
- If students have difficulty pouring the samplesinawaythat allows them to see how the samples layer, try to get them to figure out what they can do differently to make it easier. If they are unable to figure out an alternative procedure on their own, you may offer them these tips:
  - Pour the lighter color (for example, yellow) first and the darker color (for example, blue) second. This makes it easier to see the line between layers.
  - Pour a small amount of water slowly and carefully.
  - Tilt the beaker or cup while pouring the second sample.
  - Do not wait until you have finished pouring to watch what is happening with your samples. Watch what happens the instant the two samples hit. The longer they are in contact, the likelier they are to mix, making it too hard to tell which layer is on top.
- Students should record the results of their comparisons on their data sheets.
- Once they have completed their four comparisons, students should answer the other questions on their data sheets, constructing an argument from evidence about the implications of the findings.

PROGRAM OUTLINE CONTINUED:

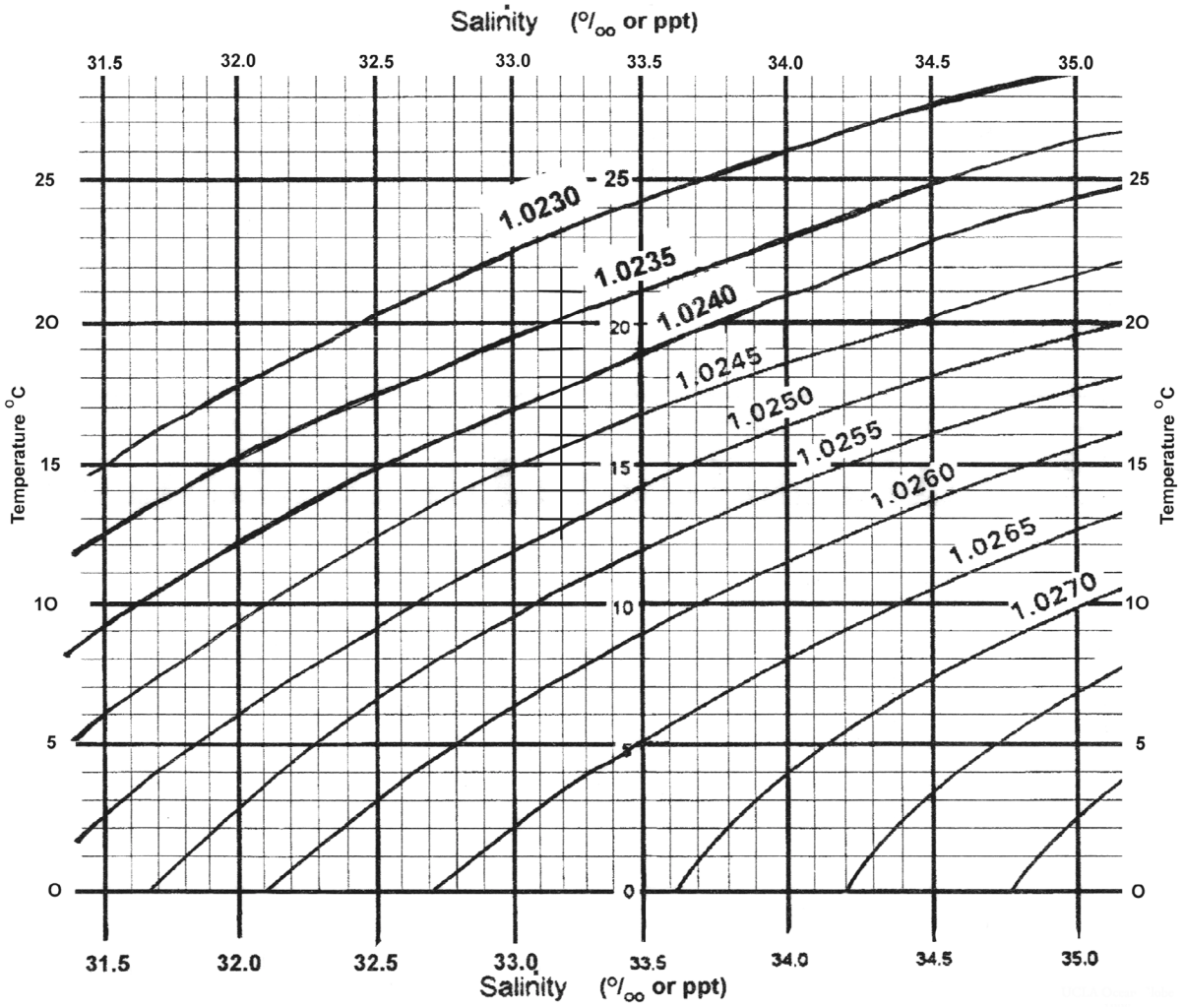
Debrief

- Once each group has completed the investigation and constructed their argument from evidence, have each group share their results and argument with at least one other group.
- Have them compare, contrast, and discuss their results.
- Gather the whole class together. Discuss students' findings and hypotheses as a group. What did they discover? What do they think the connection is between temperature, salinity, and the way water layers?
- Introduce the idea of density. Explain the connections among temperature, salinity, and density. These relationships explain the results of their investigation.

TEACHER BACKGROUND:

Temperature and salinity are two important characteristics of water that impact its physical properties, notably its density. The theoretical density of water is 1 gram per cubic centimeter. However, this is only the actual density of water when it is at certain temperatures and salinities; based on differences in temperature and salinity, the density of water varies widely. As temperature decreases, the density of water increases, meaning cold water is denser than warm water. This trend changes around 4ºC, when water becomes less dense as it approaches freezing. Salinity has an even greater impact on the density of water. As salinity increases, density increases, meaning saltwater is considerably denser than freshwater. The graph below demonstrates these relationships and how temperature and salinity work in concert to impact the density of water.

Temperature Density Salinity Conversion Chart



OceanGLOBE, UCLA Marine Science Center: http://www.msc.ucla.edu/oceanglobe/

GLOSSARY:

Density: Amount of matter in a given area; calculated by dividing mass by volume

Salinity: Measure of the amount of dissolved salt in water; usually measured in parts per thousand (ppt or ‰)

Temperature: Measure of the average kinetic energy of particles within a given object; measured in degrees Celsius, Fahrenheit, or Kelvin

8TH GRADE STANDARDS:

California Science Content Standards

- 8.a. Students know density is mass per unit volume.
- 9.a. Plan and conduct a scientific investigation to test a hypothesis.

California Next Generation Science Standards

- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
  - Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
  - Analyze and interpret data to determine similarities and differences in findings.
- MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
  - Plan an investigation, individually and collaboratively, and in the design identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
  - Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
  - Construct, use, 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.

Planning and Carrying Out Investigations

- Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

California Common Core Standards

ELA/Literacy

- W8.1.b. Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating and understanding of the topic or text.

Name: _____

Date: _____

TEMPERATURE AND SALINITY INVESTIGATION DATA SHEET

1. Draw the results of your four comparisons in the space below.

2. If you were able to layer all four types of water in one beaker, what do you think it would look like? Explain your reasoning, providing evidence from the four comparisons you made.

3. What do you think this indicates about the relationship between temperature and salinity and the way different water will layer? Explain your reasoning.

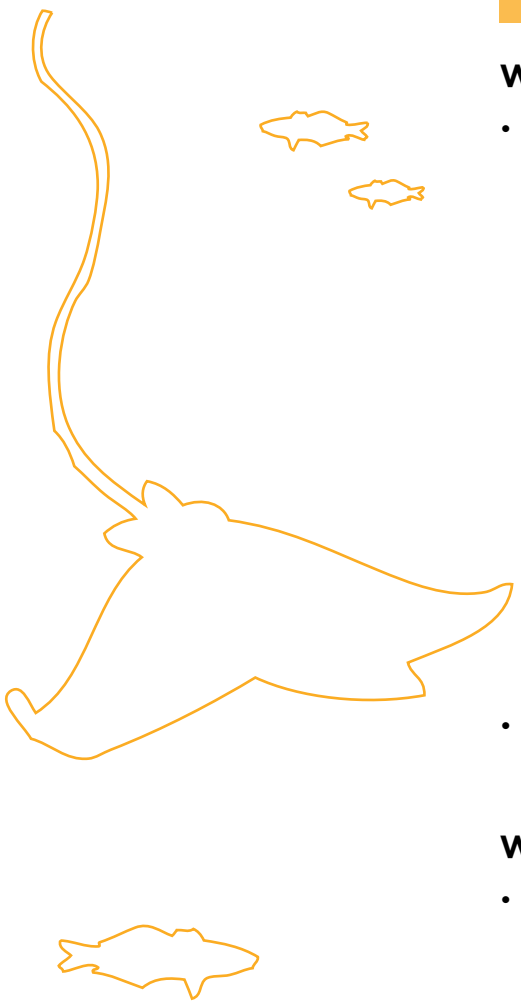
LESSON 2

TEMPERATURE, SALINITY, AND DENSITY 101

Enduring Understanding: The density of water is calculated as mass over volume and is influenced by both the temperature and salinity of the water.

Materials

• "Temperature and Salinity Investigation" data sheets



SETUP:

1. Make copies of the "Temperature, Salinity, and Density" worksheets.

PROGRAM OUTLINE:

Why do the temperature and salinity of water matter?

- The temperature and salinity of water are important because they impact its physical and chemical characteristics, as well as its suitability for use, consumption, and habitat by humans and other organisms.
    - People and most land animals cannot survive by drinking saltwater. Most plants will die if watered with saltwater.
    - If you took an ocean-dwelling animal like a great white shark and put it in freshwater Lake Tahoe, it would not be able to survive. The same would apply if you took a goldfish and put it in the Pacific Ocean. The salinity of water, in part, determines what can live in it.
    - The same is true of the water's temperature. A cold-water animal like a lion's mane jellyfish or Chinook salmon cannot live in tropical waters; a warm-water animal like a staghorn coral or a clownfish could not survive in frigid Arctic waters.
- Density is one of the physical characteristics of water impacted by temperature and salinity.

What is density?

- Density is the amount of matter in a given amount of space.
    - It is calculated by dividing mass by volume.
    - Pure water's density is about 1 gram/cubic centimeter, but it varies greatly based on a number of factors, including temperature and salinity.

PROGRAM OUTLINE CONTINUED:

How is water's density impacted by its temperature and salinity?

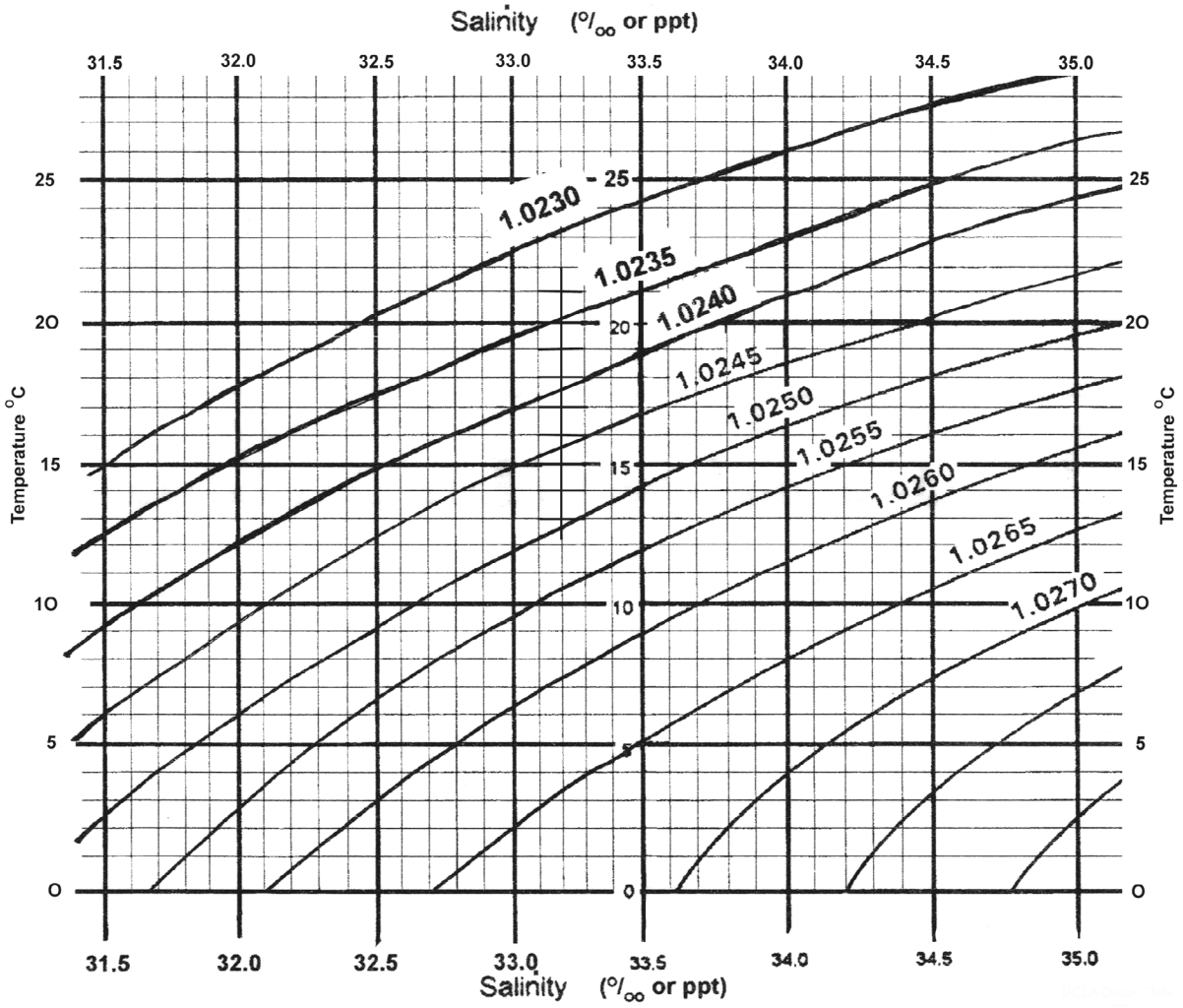
- Students will work in small groups to investigate this relationship using the "Temperature, Salinity, and Density" charts and filling out the worksheet.
- When students are done, gather them together to share their findings.
- Check for understanding.
    - Density is mass over volume.
    - As water's salinity increases, its density increases.
    - As water's temperature increases, its density decreases.

TEACHER BACKGROUND:

Temperature and salinity are two important characteristics of water that impact its physical properties, notably including its density. The theoretical density of water is 1 gram per cubic centimeter. However, this is only the actual density of water when it is at certain temperatures and salinities; based on differences in temperature and salinity, the density of water varies widely. As temperature decreases, the density of water increases, meaning cold water is denser than warm water. This trend continues until around 4ºC, at which water is its densest.

Salinity has an even greater impact on the density of water. As salinity increases, so does density, meaning saltwater is considerably denser than freshwater. The graph below demonstrates these relationships, and how temperature and salinity work in concert to impact the density of water.

Temperature Density Salinity Conversion Chart



OceanGLOBE, UCLA Marine Science Center: http://www.msc.ucla.edu/oceanglobe/

GLOSSARY:

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8TH GRADE STANDARDS:

California Science Content Standards

- 8.a. Students know density is mass per unit volume.

California Next Generation Science Standards

- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
  - Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
- MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
  - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.
- MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
  - Graphs and charts can be used to identify patterns in data.

California Common Core Standards

ELA/Literacy

- 8.RI.1. Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.

Name: _____

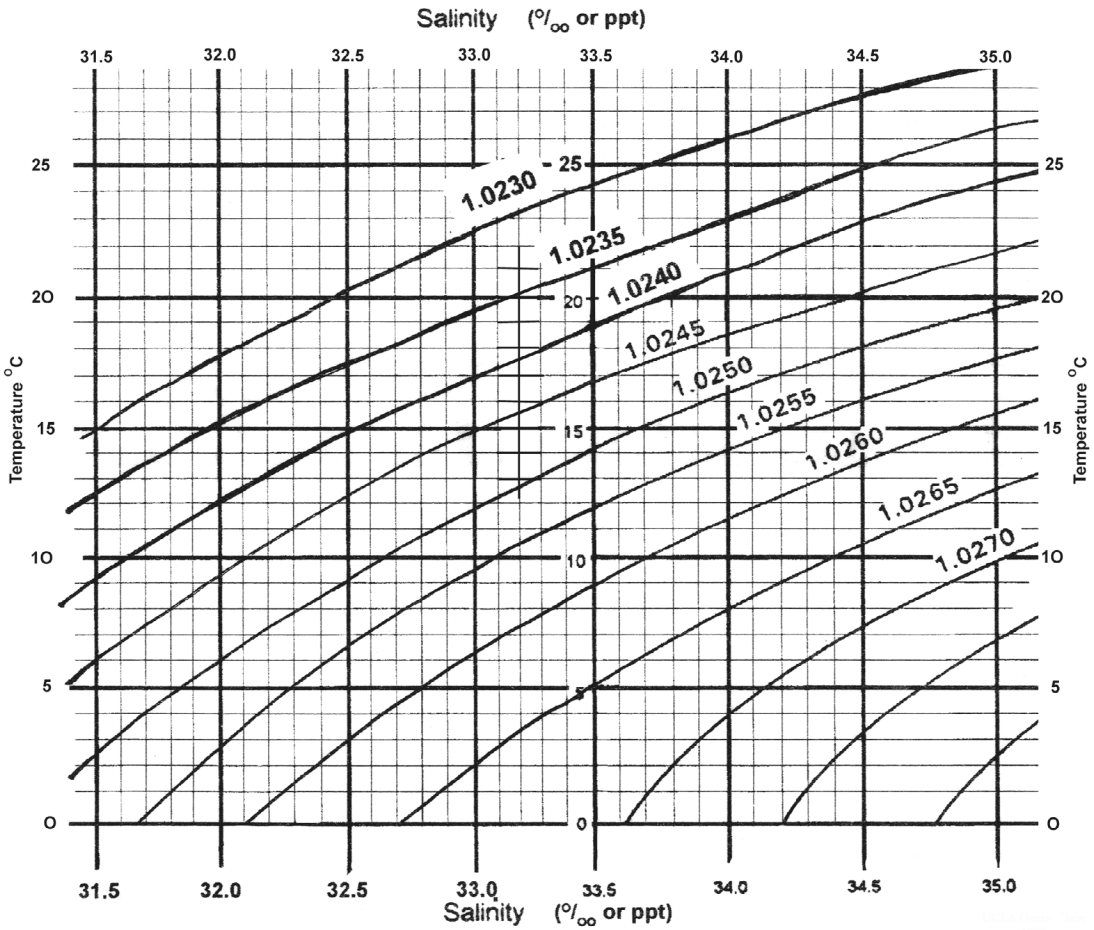
Date: _____

TEMPERATURE, SALINITY, AND DENSITY

Temperature and salinity are two important characteristics of water. Temperature measures how much heat is in a given material. It is measured in degrees Celsius or Fahrenheit. Water is liquid between 0ºC and 100ºC. Below 0ºC, water becomes solid ice. Above 100ºC, water becomes gaseous water vapor. Salinity measures how much salt is dissolved in water. It is measured in parts per thousand (ppt or ‰). Freshwater has a salinity of 0‰, while ocean water is around 35‰. Temperature and salinity also influence another important characteristic of water: density. Density measures how much matter is in a given amount of space. It is calculated using the equation Density = Mass/Volume. Water's density is often measured in grams per cubic centimeter (g/cm3).

This graph shows how water's temperature, salinity, and density are related to each other.

Temperature Density Salinity Conversion Chart



OceanGLOBE, UCLA Marine Science Center: http://www.msc.ucla.edu/oceanglobe/

TEMPERATURE, SALINITY, AND DENSITY CONTINUED

In the graph, the density of water is shown on the curved diagonal lines and is measured in g/cm3.

Use the graph and information above it to answer the following questions. Make sure to include units as needed.

1. As water's temperature increases, its density _____.

2. As water's salinity increases, its density _____.

3. If water is at 15ºC and has a salinity of 33‰, its density is _____.

4. If water is at 3ºC and has a salinity of 32.5‰, its density is _____.

5. If water is at _____ and has a salinity of 33.5‰, its density is 1.024 g/cm3.

6. If water is at _____ and has a salinity of 35‰, its density is 1.027 g/cm3.

7. If water is at 26ºC and has a salinity of _____, its density is 1.023 g/cm3.

8. If water is at 9ºC and has a salinity of _____, its density is 1.024 g/cm3.

9. Rank the following from least dense to most dense:
    a. _____ Colder, saltier water
    b. _____ Warmer, saltier water
    c. _____ Colder, less salty water
    d. _____ Warmer, less salty water

10. Would this graph be more useful if you wanted to find the density of water from the Sacramento River or from the Pacific Ocean? Why? _____

_____

_____

_____

_____

_____

Name: TEACHER KEY

Date: _____

TEMPERATURE, SALINITY, AND DENSITY

Temperature and salinity are two important characteristics of water. Temperature measures how much heat is in a given material. It is measured in degrees Celsius or Fahrenheit. Water is liquid between 0ºC and 100ºC. Below 0ºC, water becomes solid ice. Above 100ºC, water becomes gaseous water vapor. Salinity measures how much salt is dissolved in water. It is measured in parts per thousand (ppt or ‰). Freshwater has a salinity of 0‰, while ocean water is around 35‰. Temperature and salinity also influence another important characteristic of water: density. Density measures how much matter is in a given amount of space. It is calculated using the equation Density = Mass/Volume. Water's density is often measured in grams per cubic centimeter (g/cm3).

This graph shows how water's temperature, salinity, and density are related to each other.

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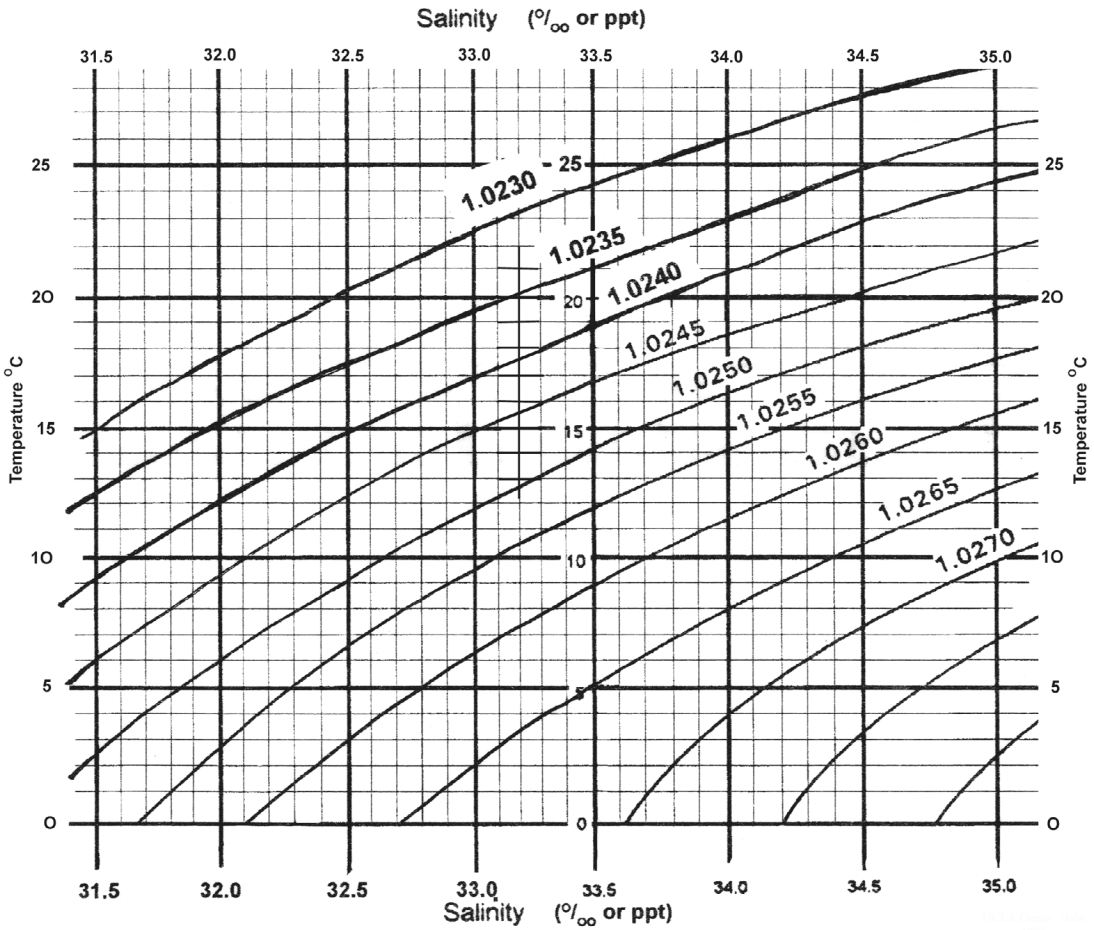

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TEMPERATURE, SALINITY, AND DENSITY CONTINUED

In the graph, the density of water is shown on the curved diagonal lines and is measured in g/cm3.

Use the graph and information above it to answer the following questions. Make sure to include units as needed.

1. As water's temperature increases, its density _____decreases_____.

2. As water's salinity increases, its density _____increases_____.

3. If water is at 15ºC and has a salinity of 33‰, its density is _____1.0245_____.

4. If water is at 3ºC and has a salinity of 32.5‰, its density is _____1.0260_____.

5. If water is at _____19º_____ and has a salinity of 33.5‰, its density is 1.024 g/cm3.

6. If water is at _____10º_____ and has a salinity of 35‰, its density is 1.027 g/cm3.

7. If water is at 26ºC and has a salinity of _____34‰_____, its density is 1.023 g/cm3.

8. If water is at 9ºC and has a salinity of _____31.5‰_____, its density is 1.024 g/cm3.

9. Rank the following from least dense to most dense:
   a. ____4____ Colder, saltier water
   b. ____3____ Warmer, saltier water
   c. ____2____ Colder, less salty water
   d. ____1____ Warmer, less salty water

10. Would this graph be more useful if you wanted to find the density of water from the Sacramento River or from the Pacific Ocean? Why?

Answers will vary. The key points are:

- The graph would be more useful for finding the density of water in the Pacific Ocean than in the Sacramento River.
- The graph only shows salinities between 31.5 and 35 parts per thousand, and the informational text explains ocean water, like the water in the Pacific Ocean, is roughly 35 parts per thousand, and freshwater, like the water in the Sacramento River, is 0 parts per thousand.
- This means the graph could be used on ocean water, but it does not cover anywhere near the salinity (0 parts per thousand) that would be expected in a freshwater river. Without the necessary data for salinity there would be no way to use the graph.

LESSON 3

FORMING AND MELTING ICE

Enduring Understanding: Phase changes of water, by melting or freezing, have an impact on its salinity and its density.

Materials

- 3 batches of tap water (one for dying and freezing ahead of time, one for making saltwater with students, and one for students to melt ice in during the investigation)
- Food coloring
- Tubs or pitchers
- Ice trays (or other small containers for freezing)
- Cups (safe for drinking)
- Salt
- Refractometers (optional)
- Freezer
- Notebooks or paper for recording findings

SETUP:

NOTE: This program requires advanced preparation.

1. The day before teaching, mix water with food coloring, making it fairly dark. Freeze the colored water in ice cube trays or other containers.
2. If your class is shorter than two hours, begin the following process for the students. If you have two hours, you may let the students do it.
    - Several hours before the start of the lesson, create three kinds of water samples: very salty, slightly salty, and freshwater. Make sure to create enough samples for each group.
    - Freeze the samples in medium-sized cups. (NOTE: Make sure they are safe for drinking.)
    - Do not put the samples in the freezer overnight. You want them to partially but not completely freeze.
3. Ensure that you have enough tubs or pitchers, cups, and other materials for each group.

PROGRAM OUTLINE:

Why do the temperature, salinity, and density of water matter?

- Briefly review the ideas of temperature and salinity in water and how they relate to density.
- These characteristics of water and how they change have real-world implications that affect all living things.
- Students will be investigating what happens when these characteristics change when the phase of the water changes from solid to liquid, or vice versa.
- Students will be responsible for taking their own notes that accurately describe what they observe and record any data

they uncover. If your students are unfamiliar with note taking without scaffolds, such as a worksheet or outline, you may supply them with one. However, as researchers often do not follow prearranged templates when taking notes during investigations or studies, starting from scratch is an important exercise. Each group may create one set of notes, or each student can create one.

Investigation 1

NOTE: If your class is shorter than two hours, begin the following process for the students.

- Have students create three water samples: very salty, slightly salty, and freshwater.
  - Have students taste test each sample.
  - If you have access to refractometers, have them test and record the salinity.
- Have students freeze the water samples in medium-sized cups.
- If possible, have students check on their samples periodically to observe different stages in the freezing process.
  - What differences do they notice among the different salinities?
  - How is the water freezing? Is it freezing from the bottom? From the top?
- Once the samples have all developed a thick layer of ice on top, have the students remove their samples from the freezer and explore them.
  - What similarities and differences do they notice among the samples?
  - What do they think is the reason behind these differences and similarities?
- Have students taste test the salinities of the different ice samples.
  - Students remove a sample of the ice from each cup.
    - They carefully and quickly rinse the sample with very cold water, taking care not to melt the entire sample.
    - Once each sample has been rinsed, put it in a new cup to melt.
    - Once each sample has melted, have the students taste each sample. Does it taste salty?
  - Alternatively, if you have access to refractometers, have the students test the salinity of each melted ice sample with the refractometers.
    - Have the students also sample the liquid water left in their samples. If you have refractometers, you can use them to test the salinity of the liquid water left in the samples.
  - Students should find that the ice is less saline than the original samples and much less saline than the liquid water that remained after freezing. This occurs because salt evacuates water as it freezes.

Investigation 2

- Provide each group with a tub, freshwater, and colored ice.
- Students will put the ice in the water and record what happens.
  - Where is the melted ice going? Does it rise to the top? Does it sink?
- Debrief
- Once each group completes the investigations, have them share their results with at least one other group.
  - Compare results.
  - What was surprising?
- What do your results suggest about the way salinity and density change during a phase change resulting from temperature changes?
  - Assemble the whole class to discuss the results.

PROGRAM OUTLINE CONTINUED:

- What are the implications of this?
    - Scientists often consider the real-world applications and implications of their study. What are the real-world implications of changing temperature, salinity, and density in water?
    - When ocean water freezes into sea ice in winter, it loses its salt, leaving that salt behind in the water. When sea ice melts in summer, it creates very cool water. Our investigations approximated these large-scale processes in nature.
    - In both cases, the water surrounding the sea ice is denser than most of ocean water. What do you think happens to it?
- It sinks, which drives the circulation of water in the oceans.
    - Why does that matter?
- This circulation, called thermohaline circulation or the global conveyor belt, plays a major role in Earth's climate.
    - One of the impacts of global climate change is that normal patterns of polar sea ice are changing, and in some cases ceasing. What implications does that have for the water and therefore the living things that depend on it? (NOTE: Lesson 4 will go into these topics in detail.)
- What can we do to keep the natural dynamics of temperature, salinity, and density in the world's oceans continuing as they should?
    - The climate change that is disrupting normal patterns of polar sea ice is the result of human activity.
- When humans burn fossil fuels—like coal, gas, and oil—by driving cars, making things in factories, and growing food, the combustion—or burning—releases carbon dioxide and other gases that were contained within the fossil fuel for millions of years.
- These gases, called greenhouse gases, are naturally occurring, but we're adding more than is supposed to be in the atmosphere. When they enter the atmosphere, they trap more heat on Earth that would otherwise go into space. This heat is warming the planet.
- That increased heat also heats up the sea ice and melts it, disrupting the normal patterns of sea ice.
    - Because these imbalances are the result of human choices, we have the power to make better choices that will help restore balance to Earth's climate.
- Brainstorm with students things they can do to make a positive difference concerning climate change. (NOTE: Lesson 4 will go into these topics in depth.)

TEACHER BACKGROUND:

Temperature and salinity are two important characteristics of water that impact its physical properties, notably its density. The theoretical density of water is 1 gram per cubic centimeter. However, this is only the actual density of water when it is at certain temperatures and salinities; based on changes temperature and salinity, the density of water varies widely. As temperature increases, the density of water decreases, meaning cold water is denser than warm water. Salinity has an even greater impact on the density of water. As salinity increases, so does density, meaning saltwater is considerably denser than freshwater.

The density of water varies most notably at or near the temperature at which phase change occurs. As water nears its boiling point of 100ºC, its molecules spread farther and farther apart, making it considerably less dense, until it vaporizes into water vapor, which has a very low density. As water approaches its freezing point of 0ºC, its molecules move closer and closer together, making it denser. This trend of water becoming increasingly dense continues until approximately 4ºC, at which point water is its densest. At temperatures below 4ºC, water actually becomes less dense. This is an unusual characteristic of water that is responsible for ice floating in liquid water. It may have played a role in the suitability of Earth for the evolution of life. This characteristic is due to the unusual molecular structure and characteristics of water, including the presence of hydrogen bonds.

Density and weight of water at standard sea-level atmospheric pressure

Temperature °F/°C	Density grams/cm3	Weight pounds/ft3	kilograms/liter
32°/0°	0.99987	62.416	0.999808
39.2°/4.0°	1.00000	62.424	0.999937
40°/4.4°	0.99999	62.423	0.999921
50°/10°	0.99975	62.408	0.999681
60°/15.6°	0.99907	62.366	0.999007
70°/21°	0.99802	62.300	0.997950
80°/26.7°	0.99669	62.217	0.996621
90°/32.2°	0.99510	62.118	0.995035
100°/37.8°	0.99318	61.998	0.993112
120°/48.9°	0.98870	61.719	0.988644
140°/60°	0.98338	61.386	0.983309
160°/71.1°	0.97729	61.006	0.977223
180°/82.2°	0.97056	60.586	0.970495
200°/93.3°	0.96333	60.135	0.963270
212°/100°	0.95865	59.843	0.958593

From the U.S. Geological Survey: http://water.usgs.gov/edu/density.html

TEACHER BACKGROUND CONTINUED:

These variations in salinity and density that occur as water undergoes a phase change from solid to liquid, or vice versa, are important drivers in Earth's ocean currents, and thus its climate. As ocean water freezes in the polar regions, salt evacuates the freezing water, increasing the salinity of the nearby water. As the water's salinity increases, so does its density. This means that the water sinks.

This sinking of dense, highly saline water at the poles drives thermohaline circulation in the world's oceans. Also known as the global conveyer belt, thermohaline circulation moves vast quantities of water in a slow-moving current that circulates throughout the world's oceans. The circulation happens extremely slowly: any one water molecule may take a thousand years or more to circulate through the conveyor belt. However, the global conveyor belt is important in regulating climate, the carbon cycle, and ocean nutrient cycles throughout the world.

One of the many expected impacts of global climate change—and one that has already been observed—is a disruption in the formation of sea ice at Earth's poles. As the patterns of sea-ice formation change, and in some cases cease altogether, the global conveyor belt of water circulating through the ocean may be disrupted, in turn further disrupting global climate and the global climate cycle.

Fortunately, there are steps that people can take, both individually and collectively, to combat climate change, including shrinking their carbon footprint. These are just a few actions that can help maintain the equilibrium of Earth's climate and prevent the disruption of the global conveyor belt:

- Make transportation choices that produce fewer greenhouse gases, including walking, biking, taking public transportation, and carpooling.
- Choose to eat foods that have a lower carbon footprint, such as vegetables and fruit, and avoid foods with high carbon footprints, such as meat (particularly beef and lamb) and processed foods.
- Shop at farmers' markets and/or choose locally made products that require fewer carbon emissions to ship.
- Reduce consumption by using what you do buy, reusing things you can, and recycling or composting what you can't.

GLOSSARY:

Carbon Footprint: Amount of climate change-causing greenhouse gases required to produce a particular product, complete a particular activity, or support the lifestyle of a particular individual or group.

Climate Change: Significant, long-term changes in weather patterns; has happened in the past but is currently happening at an accelerated rate because of human activities; (Current climate change is often referred to as global warming, but climate change is a more accurate description of the phenomenon.)

Density: Amount of matter in a given area; calculated by dividing mass by volume

Global Conveyor Belt: Slow-moving, deep-water, thermohaline currents that circulate through Earth's oceans, influencing climate, the carbon cycle, and nutrient availability

Salinity: Measure of the amount of dissolved salt in water; usually measured in parts per thousand (ppt or ‰)

Sea Ice: Massive floating body of ice in ocean ecosystems; includes icebergs and polar ice sheets

Temperature: Measure of heat within a given object; measured in degrees Celsius, Fahrenheit, or Kelvin

Thermohaline Circulation: Movement of water driven by variations in its temperature and salinity; the global-scale currents of ocean water that form the global conveyor belt

8TH GRADE STANDARDS:

California Science Content Standards

- 8.a. Students know density is mass per unit volume.
- 9.a. Plan and conduct a scientific investigation to test a hypothesis.

California Next Generation Science Standards

- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
  - Develop a model to predict and/or describe phenomena.
  - Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
  - Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
  - Analyze and interpret data to determine similarities and differences in findings.
- MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

8TH GRADE STANDARDS CONTINUED:

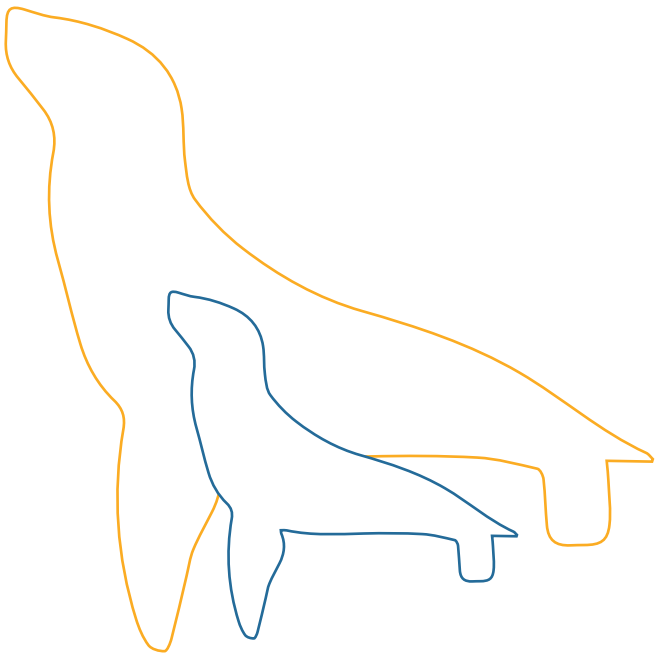
- Plan an investigation, individually and collaboratively, and in the design identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

- MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
  - Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.
- Planning and Carrying Out Investigations
  - Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

RESOURCES:

NOAA Ocean Service Education
http://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html

U.S. Geological Survey
http://water.usgs.gov/edu/density.html



LESSON 4

CLIMATE CHANGE AND THE GLOBAL CONVEYOR BELT

Enduring Understanding: Human actions either negatively or positively impact Earth's processes and climate system.

Materials

- "The Global Conveyor Belt and Climate Change" worksheets
- Computers with Internet access or other research materials (optional)

SETUP:

1. Make copies of "The Global Conveyor Belt and Climate Change" worksheets.

PROGRAM OUTLINE:

Why is the global conveyor belt important?

- Have students read the text about the global conveyor belt and answer the questions on the worksheet.
- Alternatively, you may select another text or video that discusses thermohaline circulation and climate change.
- Have students work individually or in small groups.

Debrief with students

- After the students read the text and answer the questions, bring the group together.
- Review thermohaline circulation and the physical and chemical properties of water that cause it to happen.
  - Thermohaline circulation is the movement of water caused by differences in temperature (thermo-) and salinity (-haline).
  - Variations in these characteristics of water cause variations in that water's density.
  - Water that is more saline, or saltier, is denser than less saline water. Because of this, saltier water sinks.
  - Generally, colder water is denser than warmer water, and generally colder water will sink below warmer water. However, below approximately 4ºC, water begins to expand again, making it less dense than warmer water. This is why ice floats in liquid water.
- The unique characteristics of water are responsible for thermohaline circulation, which moves water throughout the world's oceans, also known as the global conveyor belt.

PROGRAM OUTLINE CONTINUED:

- The global conveyor belt is integral to Earth's climate and may be disrupted by climate change.

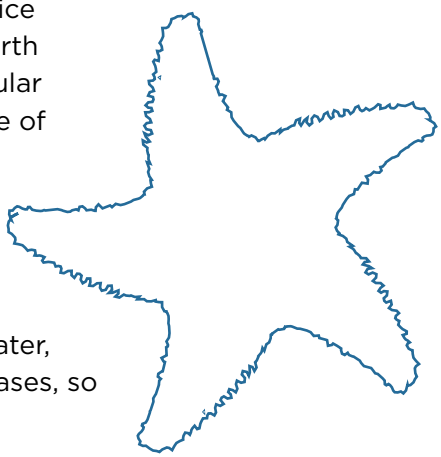
What can we do to help?

- Everyone has the ability to both contribute to climate change by producing greenhouse gas emissions and to combat climate change by reducing greenhouse gas emissions. We make choices every day that can either contribute to or mitigate the problem.
- The idea of the carbon footprint is a useful tool to help people make smart choices for the climate.
  - It shows how much of an impact a given activity, product, or way of life has in contributing to climate change.
- As a follow-up activity that can be done in the classroom or as a homework assignment, have students investigate ways they can shrink their carbon footprint. Have them focus on a specific activity they take part in or product they consume and answer the following questions:
  - What is the carbon footprint of the specific activity or product?
  - How does this activity produce greenhouse gases—both directly and indirectly?
  - Is there a way to shrink the carbon footprint of the activity or product?
  - How can students make a lower-impact choice around this product or activity?
- Examples of products or activities can include the following:
  - Foods they eat
  - Time spent on computers or smart devices
  - Mode of transportation used to get to and from school
  - Clothes they own
- When the students are done with their research and writing their responses, have them share in small groups or with the whole class.

TEACHER BACKGROUND:

Thermohaline Circulation in Earth's Oceans

The density of water varies most notably at or near the temperature at which phase change occurs. As water nears its boiling point of 100ºC, its molecules spread farther and farther apart, making it considerably less dense, until it vaporizes into water vapor, which has a very low density. As water approaches its freezing point of 0ºC, its molecules move closer and closer together, making it denser. This trend of water becoming increasingly dense continues until approximately 4ºC, at which point water is its densest. At temperatures below 4ºC, water actually becomes less dense. This is an unusual characteristic of water that is responsible for ice floating in liquid water. It may have played a role in the suitability of Earth for the evolution of life. This characteristic is due to the unusual molecular structure and molecular characteristics of water, including the presence of hydrogen bonds.

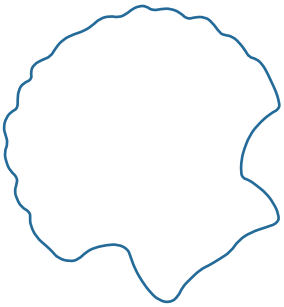


These variations in salinity and density that occur as water undergoes a phase change from solid to liquid, or vice versa, are important drivers in Earth's ocean currents and thus its climate. As ocean water freezes in the polar regions, salt evacuates the freezing water, increasing the salinity of the nearby water. As the water's salinity increases, so does its density. This means that the water sinks.

This sinking of dense, highly saline water at the poles drives thermohaline circulation in the world's oceans. Also known as the global conveyer belt, thermohaline circulation moves vast quantities of water in a slow-moving current that circulates throughout the world's oceans. The circulation happens extremely slowly: any one water molecule may take a thousand years or more to circulate through the conveyor belt. However, the global conveyor belt in important in regulating climate, the carbon cycle, and ocean nutrient cycles throughout the world.

Climate Change and the Global Conveyor Belt

Global climate change caused by human disruptions to Earth's carbon cycle is one of the most pressing social and environmental issues of our time. While climates naturally change over time, the present-day anthropogenic climate change is occurring at an accelerated and perhaps unprecedented rate, which will have—and in some cases already is having—very real implications for humans and other living things.



There are multiple human actions that contribute to the changing climate, but the main cause is the burning of fossil fuels. When people burn fossil fuels—oil, coal, and natural gas—carbon that has been chemically stored in the fuel for millions of years is released into the atmosphere as carbon dioxide, a greenhouse gas. Greenhouse gases trap heat in Earth's atmosphere, making it warm enough for life. However, when there are too many greenhouse gases in the atmosphere, it causes temperatures to rise. This results in increases in the overall temperature of the planet. But higher temperatures are not the only impact expected with climate change. Weather is driven by the way heat moves through the earth system, and adding more heat changes weather patterns, potentially leading to more extreme weather events.

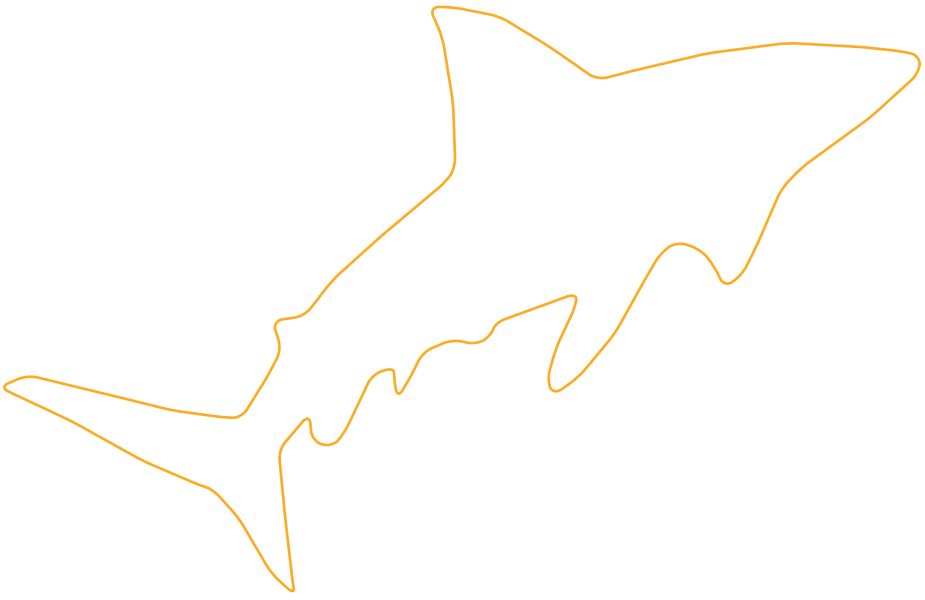
TEACHER BACKGROUND CONTINUED:

Burning fossil fuels, while the primary cause of climate change, is not the only thing humans do that is raising the temperature. Another major cause is deforestation. When people clear trees—trees that were previously breathing in carbon dioxide and photosynthesizing it into oxygen—the trees are no longer able to uptake carbon dioxide. Any carbon they would have absorbed remains in the atmosphere. Animal agriculture is another major contributor to climate change, accounting for nearly a fifth of all greenhouse gas emissions. Not only does industrialized animal agriculture require the burning of fossil fuels and contribute a major reason for deforestation, but many commonly farmed animals produce methane, a greenhouse gas many times more powerful than carbon dioxide.

One of the many expected impacts of global climate change—and one that has already been observed—is a disruption in the formation of sea ice at Earth's poles. As the patterns of sea-ice formation change, and in some cases cease altogether, the global conveyor belt of water circulating through the ocean may be disrupted, in turn further disrupting global climate and the global climate cycle.

Fortunately, there are steps that people can take, both individually and collectively, to combat climate change by shrinking their carbon footprint. These are just a few actions that can help maintain the equilibrium of Earth's climate and prevent the disruption of the global conveyor belt:

- Make transportation choices that produce fewer greenhouse gases, including walking, biking, taking public transportation, and carpooling.
- Choose to eat foods that have a lower carbon footprint, such as vegetables and fruit, and avoid foods with high carbon footprints, such as meat (particularly beef) and processed foods.
- Shop at farmers' markets and/or choose locally made products that require fewer carbon emissions to ship.
- Reduce consumption by using what you do buy, reusing things you can, and recycling or composting what you can't.



GLOSSARY:

Carbon Footprint: Amount of climate change-causing greenhouse gases required to produce a particular product, complete a particular activity, or support the lifestyle of a particular individual or group.

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Thermohaline Circulation: Movement of water driven by variations in its temperature and salinity; the global-scale currents of ocean water that form the global conveyor belt

8TH GRADE STANDARDS:

California Science Content Standards

- 8.a. Students know density is mass per unit volume.
- 9.a. Plan and conduct a scientific investigation to test a hypothesis.

California Next Generation Science Standards

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
  - 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.
  - 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-ESS2-6. Develop and use a model to describe how unequal heating and rotation of Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere,

8TH GRADE STANDARDS CONTINUED:

ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

- MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
  - Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

California Common Core Standards

- 8.W.7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Name: _____

Date: _____

THE GLOBAL CONVEYOR BELT AND CLIMATE CHANGE

The oceans are vital to all life on Earth, even to organisms that live far from them. The oceans provide oxygen for us to breathe and food and habitat for many living things. They play a major role in the planet's climate. One of the ways that the oceans help regulate climate is through something called the global conveyor belt, also known as thermohaline circulation.

NOAA Ocean Service Education http://oceanservice.noaa.gov/education/kits/currents/06conveyor2.html

The global conveyor belt is a current that moves through and connects all the world's oceans. The current is very slow. It can take a thousand years for any one water molecule to make the whole journey. It is driven by the differences in temperature and salinity in the water of different parts of the ocean. At Earth's poles, dense saltwater sinks. This starts the conveyor belt in motion. The water at the poles is particularly dense for two reasons: One, the poles are the coldest parts of the planet and so have the coldest water, and two, when ocean water freezes to form sea ice, the salt escapes the ice into the surrounding water. As the water moves around the planet on the conveyor belt, it also moves heat around the planet. By moving this heat around Earth, the global conveyor belt helps keep the temperatures and weather on land from changing too much. It keeps some parts of the world—such as Northern Europe—from getting too cold.

This process has remained relatively unchanged since the last ice age ended 12,000 years ago. But now it may be disrupted by global climate change. When humans burn fossil fuels like coal, oil, and natural gas to power cars, heat homes, and make goods, carbon that was trapped in the fuel for millions of years is transformed into carbon dioxide and other greenhouse gases, which enter the atmosphere. Other human activities like deforestation, raising animals for food, and making cement also release greenhouse gases. Once in the atmosphere, these newly released greenhouse gases trap extra heat on Earth. Carbon dioxide and other greenhouse gases naturally occur in the atmosphere, but human activity is throwing off the balance by adding more than is supposed to be there.

By trapping more heat, Earth is getting warmer overall. However, there is more to the story than things getting warmer. As the planet warms, long-term weather patterns—climates—around the world change. Two places where this is most notable are Earth's poles. These are warming faster than other parts of the planet. The cold polar waters that help drive the global conveyor belt are warming. Also, the sea-ice formation that makes polar water saltier is happening on a smaller scale. If this pattern continues into the future, it could lessen the amount of water sinking at the poles. This would slow or maybe even stop the global conveyor belt.

Fortunately, there are many ways that individuals and communities can reduce climate change impacts on the global conveyor belt and the rest of the planet. By making choices that reduce the amount of

THE GLOBAL CONVEYOR BELT AND CLIMATE CHANGE CONTINUED

greenhouse gases we put into the atmosphere, also known as our carbon footprint, we can maintain a healthy climate and keep the global conveyor belt flowing through the world's oceans.

Using evidence from the text, your previous knowledge, and your own ideas, please answer the following questions.

1. What is the global conveyor belt?

2. How does the global conveyor belt work?

3. Why is the global conveyor belt important?

4. Why is climate change an issue for the global conveyor belt?

5. How do you think a changing climate might impact humans?

THE GLOBAL CONVEYOR BELT AND CLIMATE CHANGE CONTINUED

6. How do you think a changing climate might impact other living things?

7. What are some ways that people—as individuals or as communities—can help slow climate change?

8TH GRADE

RESOURCES

NOAA Ocean Service Education

http://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html

UCLA Marine Science Center, "OceanGLOBE"

http://www.msc.ucla.edu/oceanglobe/

U.S. EPA "Climate Change Indicators in the United States"

http://www.epa.gov/climate/climatechange/science/indicators/snow-ice/index.html

U.S. Geological Survey, "Water Density"

http://water.usgs.gov/edu/density.html