GEMS® Curriculum Sequences

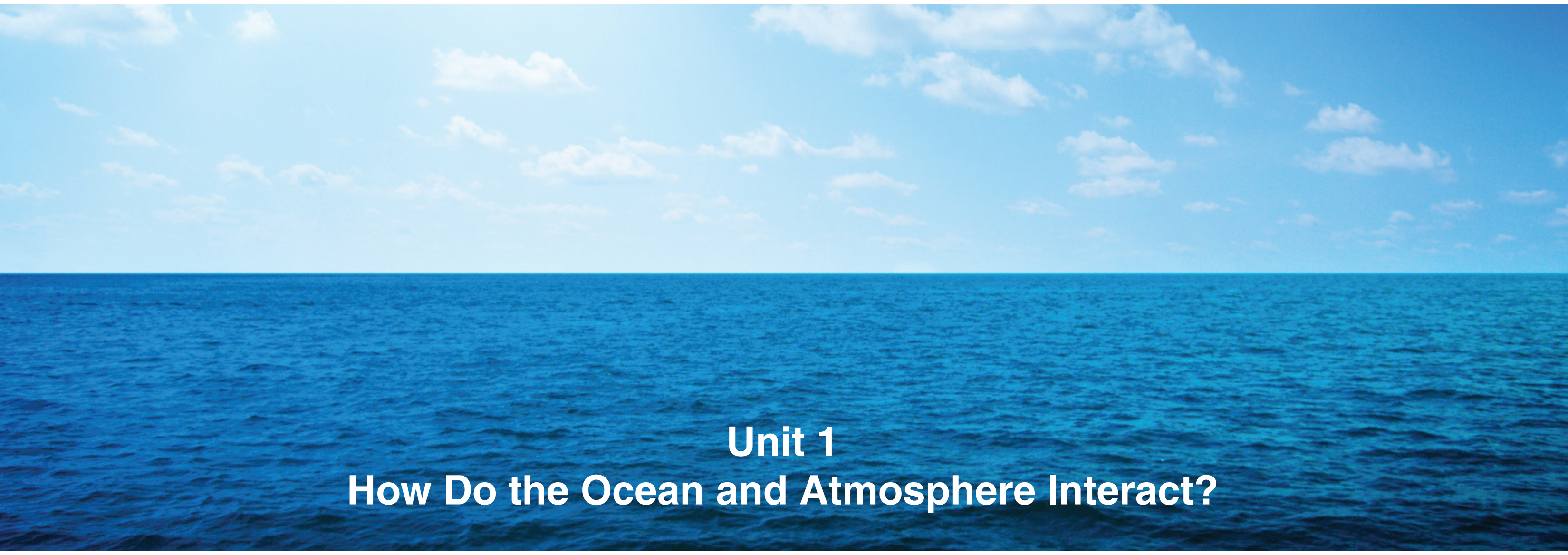
Overview & Sample Session

Ocean Sciences Sequence for Grades 6–8

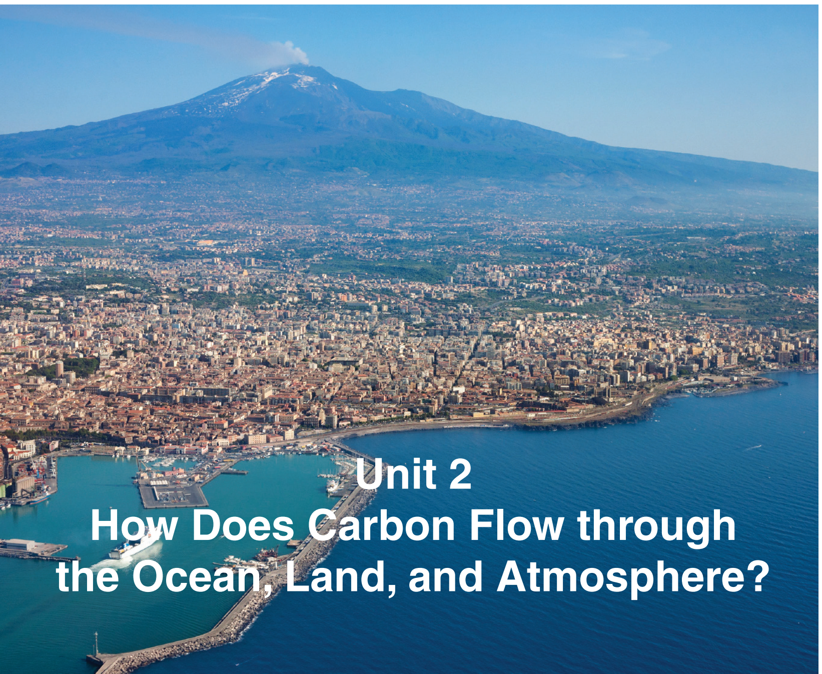
The Ocean-Atmosphere Connection and Climate Change

Introduction, Science Background, Assessment Scoring Guides

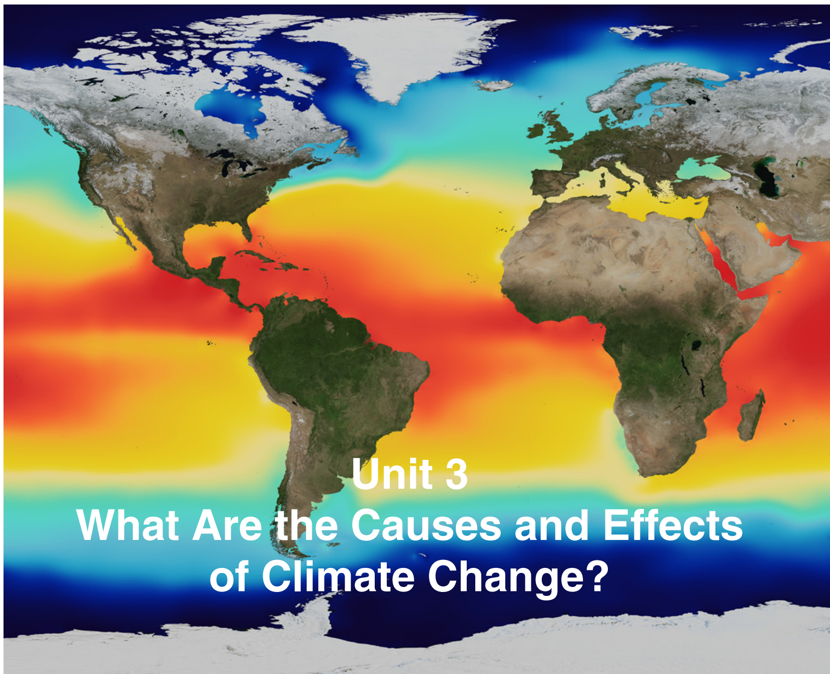
Lawrence Hall of Science • University of California, Berkeley



Unit 1
How Do the Ocean and Atmosphere Interact?



Unit 2
How Does Carbon Flow through the Ocean, Land, and Atmosphere?



Unit 3
What Are the Causes and Effects of Climate Change?

National Oceanic and Atmospheric Administration
Funding for this GEMS® *Ocean Sciences Sequence* was provided by the NOAA Environmental Literacy Grant Program.

Great Explorations in Math and Science (GEMS) is an ongoing curriculum development program and professional development network. There are more than 70 teacher's guides and handbooks in the GEMS Series. GEMS is a program of the Lawrence Hall of Science, the public science education center of the University of California, Berkeley.

Marine Activities, Resources & Education (MARE), a program of the Lawrence Hall of Science, is a whole-school interdisciplinary ocean science immersion program. MARE has provided professional development for teachers, curricular materials, and resources for families for 20 years. It is the longest running elementary and middle school marine science program in the country.

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This book is part of the GEMS *Ocean Sciences Sequence for Grades 6–8: The Ocean–Atmosphere Connection and Climate Change*.
The sequence is printed in four volumes with the following titles:
Introduction, Science Background, Assessment Scoring Guides: ISBN 978-1-4350-1046-8
Unit 1: How Do the Ocean and Atmosphere Interact? ISBN 978-1-4350-1047-5
Unit 2: How Does Carbon Flow through the Ocean, Land, and Atmosphere? ISBN 978-1-4350-1048-2
Unit 3: What Are the Causes and Effects of Climate Change? ISBN 978-1-4350-1049-9
Complete four-volume set of the GEMS *Ocean Sciences Sequence for Grades 6–8*: *The Ocean–Atmosphere Connection and Climate Change:* ISBN 978-1-4350-1045-1

www.lhsgems.org (510-642-7771)

What are GEMS® and GEMS Sequences?

Great Explorations in Math and Science (GEMS) is a widely recognized curriculum development program and professional development network. GEMS is a program of the Lawrence Hall of Science, the public science education center of the University of California at Berkeley. There are more than 70 teacher's guides and handbooks in the GEMS Series. GEMS Sequences combine the vitality and excellence of GEMS teacher's guides with greater coherence, more scientific and educational depth, systematic assessment, informational readings, and new learning technologies. The goal of each sequence is to focus strategically and effectively on the *core science concepts* that students need to understand within a scientific discipline, in alignment with a significant number and range of national, state, and district standards and benchmarks. As with GEMS teacher's guides, GEMS Sequences are tested by teachers across the United States in a wide variety of classroom settings. In addition to *Ocean Sciences Sequence for Grades 6–8, Ocean Sciences Sequence for Grades 3–5*, *Space Science Sequence for Grades 3–5* and *Space Science Sequence for Grades 6–8* are also available.

For more information on GEMS, contact:
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What is MARE?

The Lawrence Hall of Science has long been committed to national programs that help teachers, informal educators, students, and the public become more ocean literate. The Marine Activities, Resources, & Education (MARE) program at Lawrence Hall of Science is an award-winning, whole-school, interdisciplinary, ocean sciences immersion program that has provided professional development for teachers, curriculum materials, and resources for families since 1985. For additional information on professional development opportunities, see the MARE website (http://www.lawrencehallofscience.org/mare/).

MARE, in partnership with Scripps Institution of Oceanography and the College of Exploration, also serves as one of 12 existing National Centers for Ocean Sciences Education Excellence (COSEE) (http://www.coseeca.net/) and has played a leadership role in the Ocean Literacy campaign, which developed *Ocean Literacy: The Essential Principles for Ocean Sciences K–12* and *Ocean Literacy Scope and Sequence for Grades K–12* (http://www.oceanliteracy.org/).

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What Are GEMS® Sequences?

GEMS Sequences combine the vitality and excellence of GEMS Teacher's Guides with greater coherence, more scientific and educational depth, systematic assessments, informational readings, and new learning technologies. The purpose of a GEMS Sequence is to provide an effective and time-efficient way to teach the key concepts of a particular subject area and to give students the opportunity to be scientists as they, in turn, learn how scientists inquire about space and earth sciences. The goal of each Sequence is to focus strategically and effectively on the *core science concepts* that students need to understand within a scientific discipline. Sequences provide numerous opportunities for students to engage in investigations and make evidence-based explanations. The sessions have been designed in accordance with the latest research on human learning. A significant number of core science content and the practices of science as described in the *Framework for K–12 Science Education* and the Next Generation Science Standards (NGSS) are addressed in depth throughout this Sequence; correlations to NGSS can be found on the website http://mare.lawrencehallofscience.org/oss68 (Oceans) and http://www.lhsgems.org/SpaceSciSeq.htm (Space Science). Sequences have been classroom tested by teachers across the United States in a wide variety of classroom settings.

Nine Key Features of GEMS Sequences

1. **Flexibility of Use of the Curriculum.** A sequence is composed of three or four units, each lasting between four and twelve sessions. Each unit builds upon knowledge from previous units. Although a sequence is carefully designed with an overall learning progression in mind, each unit is also designed to be effective when inserted into a different curricular context. A sequence can be used in different ways, depending on standards and curriculum requirements. Some educators may sequence units *horizontally*, implementing all the units in a single grade during one school year. Others may sequence units *vertically*, teaching individual units in consecutive grades over two or three years. Still others may use only one or two units to meet specific goals and/or to integrate with other instructional materials. If you choose to use one unit independently from the other units in a sequence, the Teacher's Guide provides information about prerequisite concepts.

2. **Strong Support for Teachers.** The Teacher's Guide describes how to present the sequence and also serves as a source of professional development for teachers. The Introduction book describes how to use the materials and provides scientific and pedagogical information. In the main body of the Teacher's Guide, the step-by-step lesson plan is on the left-hand page of each two-page spread. On the right-hand page of each two-page spread are Teacher Considerations, which provide teachers with insight and advice related to the lesson and to broader pedagogical issues, including:

   - **Assessments:** Quick Checks for Understanding, Critical Junctures, and Embedded Assessments offer ways to monitor students' progress toward key learning goals.
   - **English Language Learners:** optional accommodations increase English language learners' access to the activities.
   - **Instructional Rationale:** provide goals for specific activities and reasoning behind suggested procedures.
   - **Instructional Routines:** notes about repeated procedures and routines that will become familiar to teachers and students, which facilitate ease of instruction.
   - **Instructional Suggestions:** alternative presentation options and tips on leading discussions and other activities.
   - **Providing More Experience:** optional activities to prepare students for an activity, reinforce key science ideas, or extend students' learning.
   - **Science Notes:** scientific information and common alternative conceptions.

3. **Assessment System.** GEMS Sequences use a multileveled, systematic approach to assessments. The assessment system is designed to gauge students' learning and to inform teachers on how and when to adjust instruction to ensure that students understand the content and gain needed skills. The assessment system, beginning on page 80, provides more detailed information about the assessment system used in this sequence. The assessment system includes the following types of assessments:

    - **Quick Checks for Understanding:** opportunities to briefly evaluate students' understanding and/or abilities. These are highlighted opportunities for assessment within the activities, focusing on the practices of science, such as using models and making evidence-based explanations, as well as on science content understandings.
    - **Critical Junctures:** points at which the teacher may assess a particular understanding or skill that is crucial to students' success in subsequent activities. At these junctures, there are suggestions (Providing More Experience notes) for students who may benefit from additional activities to improve their understanding.
    - **Embedded Assessments:** opportunities for teachers to assess students' written work based on a scoring guide. Each unit in a sequence includes one central formative assessment that students take during the first session of the unit, revisit at key points during the unit, and take again (often a more sophisticated version) at the end of the unit. In *Ocean Sciences Sequence for Grades 6-8*, this assessment is an Embedded Assessment based on a writing prompt.
    - **Summative Assessments:** Some sequences, such as *Ocean Sciences Sequence for Grades 6-8*, include summative assessments intended to be used in a pretest/posttest fashion and to provide a measure of student learning over an entire unit. Assessment materials are found in the Copymaster Packet for each unit.

4. **Key Concepts and the Concept Wall.** The ideas that are most important for students to understand were derived from the *Next Generation Science Standards*, *Ocean Literacy: The Essential Principles of Ocean Sciences K–12* (http://www.oceanliteracy.net), *Climate Literacy: The Essential Principles of Climate Science*, and experts in ocean/climate sciences and education. Each sequence emphasizes important ideas that research indicates are commonly misunderstood by students and are developmentally appropriate for the age range. In addition to developing science content knowledge, special attention is placed on student understanding of scientific habits of mind and the practices of science. These understandings and abilities are interwoven through activities, student readings, and assessments. As key concepts are introduced, they are explicitly shared with students in appropriate language and recorded in student notebooks and/or posted on classroom *concept walls.* As a unit or the entire sequence builds, these key concepts form a framework—or concept map—for students as they gain increased familiarity with and understanding of these essential ideas. The clear delineation and discussion of key concepts aligns with research that supports making learning goals explicit to students. The key concepts are highlighted on the first left-hand page of each session and are listed in the At-a-Glance Charts, beginning on page 26.

5. **Engaging in Investigations.** Students work collaboratively to engage in firsthand investigations. They do what scientists do—observe, ask questions, measure, record, discuss, compare, use models, analyze data, and gather evidence—which leads to deeper understanding. Through their classroom investigations, students develop an understanding of the nature and practices of science.

6. **Meaning-Making Discussions and Writing.** For deep learning of key concepts, students need opportunities to grapple with intriguing and challenging ideas. Students are then able to decide whether those ideas are supported by the available evidence. Understanding is often best achieved through reflection and thoughtful discussion during which students have the opportunity to explain their ideas to peers and the teacher as they engage in active learning and make explanations from evidence. Students need much guidance and practice in developing the skills of evidence-based

argumentation. Sequences include small-group, structured discussions designed to deepen learning and foster the language of scientific argumentation. There are also less-structured discussions; partner discussions; and large-group, teacher-moderated discussions. Writing assignments provide further opportunities for students to review concepts and practice evidence-based argumentation.

7. **Student Readings.** Student readings in each unit extend and deepen student learning and directly reinforce science concepts addressed in the units. Each reading provides a real-life historical example of the ongoing story of scientific exploration or a specific explanation or description related to core science content. In many readings, emphasis is placed on how an investigation helped advance understanding by gathering evidence. Some readings are integrated into the sessions, and other readings are optional extensions. Some readings have core information on the first page and more details or complexity on the second page. This allows for natural scaffolding for students with varied reading abilities.

8. **Vocabulary Development.** Key vocabulary words for each unit—targeted for the development of conceptual understanding—are listed in the margin of each right-hand page of the Teacher's Guide. The vocabulary words are chosen carefully to support the key conceptual learning goals of each unit and are used strategically in the presentation of sessions and readings. They are also used as reminders for the teacher to incorporate this vocabulary into classroom discussion and teaching as often as possible. Vocabulary words highlighted in bold type are those that are used in that session. A glossary (on pages 102–103) includes short, student-friendly definitions for teachers to use as necessary when clarifying definitions for students.

9. **Technology Component.** A resource disc containing all the required videos, animations, interactive simulations, and slide images, as well as PDF files of all Investigation Notebook pages, copymasters, color sheets, and card sets is included in the purchase of a printed version of this teacher's guide. In addition, you can go to the website maintained by the Lawrence Hall of Science (http://mare.lawrencehallofscience.org/oss68), which includes many of the required resources, links by session to supplemental resources, and correlations to the Next Generation Science Standards.

   Sharing both moving and still images (videos, animations, simulations, and slides) is essential to presenting the units, but the choice of equipment to project the images can be tailored to available equipment: a computer connected to an LCD projector, a computer connected to a monitor (large enough for the whole class to view the screen), a SMART® Board, or multiple computers in a computer lab. In addition, a document camera will enhance teaching and sharing during this unit. If you have access to a document camera, suggested opportunities are noted in the sessions.

Unit 1: How Do the Ocean and Atmosphere Interact?

12 sessions (45 minutes/session)

Students learn ways Earth's ocean and atmosphere interact to form currents, distribute heat energy, and keep the water cycle in motion, and they learn how these interactions drive weather and climate. Physical investigations, computer molecular models, and climate data help students discover that water acts a heat reservoir and expands when heated. Students solve a mystery of floating and sinking balloons to learn about density. They investigate model ocean currents in tanks holding water of different temperatures and salinities. With what they have learned about density differences and ocean currents, students make sense of air currents (wind). A mystery of a recurring weather pattern helps students review their learning so far, and connect it to the water cycle. Then students use another physical model to explore how wind causes surface ocean currents. They read an article about El Niño that emphasizes the complexity of the ocean-atmosphere system. Throughout the unit, students learn about the practices of science, with a focus on scientific explanations and the role of evidence.

Science content goals

- The Ocean as a Heat Reservoir
- Density and Movement of Ocean and Air Currents
- Water Cycle

Unit 2: How Does Carbon Flow through the Ocean, Land, and Atmosphere?

9 sessions (45 minutes/session)

Students learn that carbon flows among reservoirs on Earth through processes such as respiration, photosynthesis, combustion, and decomposition, and that combustion of fossil fuels is causing an imbalance in this carbon cycle. Students explore a set of Carbon Cards to discover that carbon is found in all living things and many other parts of the Earth system. They conduct an experiment with yeast and learn that organisms consume carbon, and then release it as CO_2. They read and analyze evidence about photosynthesis and observe a video animation showing plants' absorption of CO_2 at different times of the year. They read and discuss short articles to discover what can happen to the carbon in an organism after it dies. Students explore a computer model and manipulate a desktop model of the carbon cycle. They use math to investigate industry's impact on the carbon cycle, and they read about ocean acidification. Throughout the unit, students learn about the practices of science, with a focus on scientific explanations and the role of evidence.

Science content goals

- Carbon Cycle

Unit 3: What Are the Causes and Effects of Climate Change?

12 sessions (45 minutes/session)

Students learn about the causes of climate change and the effects on sea level, currents, and organisms, and then they investigate possible solutions. Through information cards, graphs, and readings, students learn about changes to the atmosphere and ocean over the course of Earth's history. They discover how carbon dioxide affects temperature, using a computer simulation and graphs. They explore evidence of the effects of climate change from photographs, short readings, and a physical model. Through a video, a desktop model, a computer simulation, and a reading, students explore how climate change affects currents. They read about effects on organisms and about possible solutions. At various points in the unit, they create cause and effect chains to synthesize their learning. Students learn that the climate change occurring now is caused by CO_2 added to the atmosphere by human industry. Throughout the unit, students learn about the practices of science, with a focus on scientific explanations and the role of evidence.

Science content goals

- Climate Change

Unit 1: How Do the Ocean and Atmosphere Interact?

1.1 Heat Energy and Moving Molecules Students write their first ideas about how water moves on Earth. They make observations and discuss their ideas about a demonstration of heated water in a bottle and a computer simulation of moving water molecules. They learn about thermal expansion, an important concept in understanding water density and currents.

1.2 Water vs. Air Students record, compare, and discuss what happens when heat energy is added to water and air bottles, then see a computer simulation showing a molecular model of the phenomenon. They discover that water is a heat reservoir.

1.3 The Ocean as a Heat Reservoir A dramatic demonstration and a reading are used to review the concept that water is a heat reservoir. Students then apply what they have learned to solve a mystery about temperatures in two locations.

1.4 Temperatures around the World Small groups of students engage in lively discussions to solve three mysteries having to do with temperatures in different places on Earth.

1.5 Mystery of the Floating Balloons Groups of students test three balloons, each filled with water of a different temperature and salinity, as they try to discover what might have been inside the teacher's mystery balloons. The concept of density is introduced.

1.6 Balloon Simulations Students relate the results from the balloon investigations to ideas about density and molecules. Groups of students design more balloon investigations and test them as a class, using a computer simulation.

1.7 Investigating Currents Groups of students investigate different currents at nine stations set up around the room. At each station, they observe and record how different temperatures and salinities of colored water move in a tank.

1.8 Making Sense of Ocean Currents "Expert pairs" each explain the results of one investigation of currents, using what they learned about the relative densities of warm, cold, and salty water. Two short videos introduce convection currents in the ocean.

1.9 Moving Air Students write a paragraph and complete a diagram about how water moves on Earth. They then apply their knowledge of density to air movement. Students solve a mystery about the direction of winds at the coast.

1.10 The Puzzling Case of the Daily Rains Students discuss a weather pattern in Costa Rica and discover connections between the ocean and atmosphere. They observe a "cloud-in-a-jar" and write about evaporation and condensation in terms of water molecules and heat energy.

1.11 Global Winds and Ocean Surface Currents Tanks of water and straws model the ocean and wind-driven currents, helping students understand how winds set ocean surface currents in motion. They also consider ways currents are directed by other influences, such as continents. Students then use maps of ocean currents to solve nautical challenges.

1.12 Ocean Currents, Global Winds, and El Niño Students read about a change in the Pacific trade winds and ocean currents that results in large global effects. They write a paragraph and complete a diagram about how water moves on Earth.

Unit 2: How Does Carbon Flow through the Ocean, Land, and Atmosphere?

2.1 Finding Out about Carbon Students write their first ideas, telling what they know about carbon. Students then read, discuss, and sort Carbon Cards and watch a short animated video. Students learn where on Earth carbon is found and what a carbon reservoir is.

2.2 Tracking Carbon through Respiration Students feed yeast samples and use an acid indicator to answer the question, "what does eating have to do with producing carbon dioxide?" Students learn that many organisms consume solid carbon in food and release carbon dioxide gas. They begin work on a Carbon Cycle Diagram that they will add to throughout the unit.

2.3 Tracking Carbon through Photosynthesis, Part 1 The class examines photographs of an investigation with a plant in a jar with water and an acid indicator and it is established that plants take in CO_2 during photosynthesis. Groups then read and discuss evidence cards to answer the question, "where does most of the matter in a plant come from?"

2.4 Tracking Carbon through Photosynthesis, Part 2 Students explore some of the ways carbon flows between animals, plants, and the atmosphere. They add to their Carbon Cycle Diagrams, and write descriptions of some ways carbon flows between reservoirs. An animated video and interpreting a graph help students discover that CO_2 levels fluctuate seasonally through the year because plants absorb much more CO_2 when they are growing.

2.5 Investigating Carbon in the Ocean Students learn that organisms in the ocean use carbon dioxide for photosynthesis and for building shells, and students discuss how that carbon gets into the ocean. Students conduct two investigations to discover that water absorbs CO_2 from the air above it.

2.6 Detecting Decaying and Buried Bodies Each student reads one of four short articles to gather evidence about the question, What happens to the carbon in organisms after they die? They share in groups of four and learn that organisms can decompose, or they can get buried in places without oxygen and over millions of years, convert into fossil fuels or limestone. Students then make flow chart "chains" with Carbon Cards to discuss and show their understanding of carbon flow.

2.7 Investigating Combustion and the Carbon Cycle Students use a set of Flow cards to discover natural ways carbon can leave limestone and fossil fuel reservoirs. The teacher burns a candle to demonstrate how burning fossil fuels can move carbon from this reservoir to the atmosphere. The class then explores a computer model and a desktop model of the carbon cycle.

2.8 Crunching the Numbers for the Carbon Cycle A computer model is used to introduce measurements of flows and reservoirs of carbon. Students use Carbon Cycle Cards with these measurements to create tabletop diagrams of the carbon cycle. Students compute totals for various types of flows and conclude that flows from human industry are causing an imbalance in the carbon cycle.

2.9 Connecting Changes in Carbon Flow and the Ocean Students read and discuss an article, and discover that as carbon dioxide increases in the atmosphere, it is also increasing in the ocean, which is changing the chemistry of the ocean water and affecting ocean organisms. Students write their revised ideas, wrapping up what they have learned in the unit.

Unit 3: What Are the Causes and Effects of Climate Change?

3.1 Introducing Earth's History Students write their initial ideas about climate change. Using cards, groups create a timeline of major changes in Earth's atmosphere throughout history, gaining a sense of deep time and rate of change for those events.

3.2 Tracking Earth's CO_2 through Time Students learn about interpreting graphs and how scientists collect data about atmospheric CO_2 levels throughout Earth's history. They analyze millions of years of Earth's atmospheric CO_2 data and learn that the rate of change since 1960 is much faster than any other known time in Earth's history.

3.3 What Does CO_2 Have to Do with Temperature? Through use of a computer simulation and interpretation of graphs, students learn about the Greenhouse Effect. They learn that as atmospheric CO_2 levels rise on Earth, so does Earth's temperature.

3.4 Reflecting on Carbon and Climate Change Through writing and discussion, students reflect on the connections between atmospheric CO_2 and global temperatures. They explore the difference between weather and climate and the definition of climate change.

3.5 Investigating Climate Change: Evidence Stations Students investigate evidence about three effects of climate change—rising sea level and shrinking glaciers and sea ice, using a Model Glacier as well as maps, graphs, and photographs at learning stations around the room.

3.6 Demonstrating Cause and Effect Students debrief the stations from Session 3.5. Groups use Cause and Effect cards to create flow charts showing a chain of causes and effects, which help them make causal connections between events related to climate change.

3.7 Investigating Climate Change: Ocean Currents Students review how climate change not only affects ocean temperatures, but also how salty the ocean is in certain areas. Through video observation, a desktop model and a computer simulation, students learn about present day global ocean circulation as well as how circulation may change with a warming climate.

3.8 Connecting Climate and Ocean Currents Students read and discuss an article reinforcing the idea that climate affects currents, which also explains how the converse is true: changes in currents can affect climate.

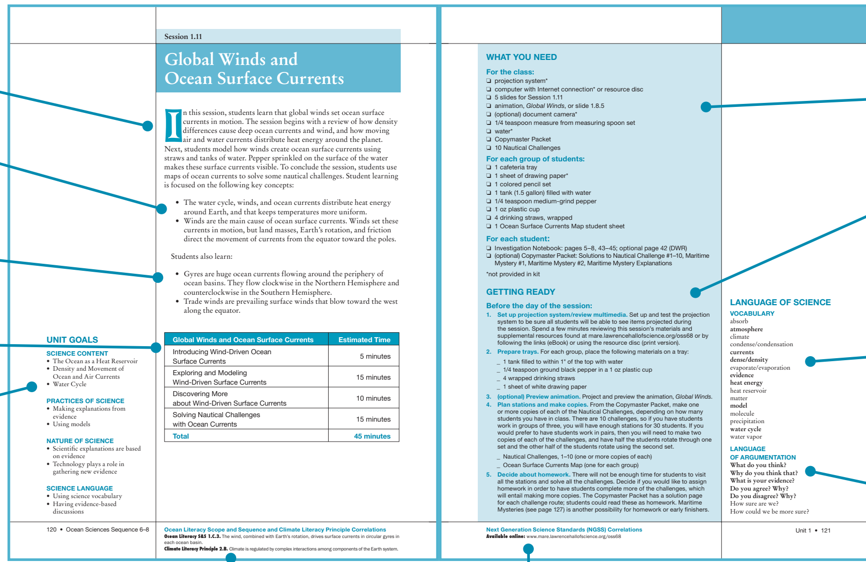
3.9 Investigating Climate Change: Organisms First, students brainstorm the effects of climate change on organisms, then they choose one of seven articles to read, discuss, and share with the class. They learn that climate change affects organisms all over the planet.

3.10 Solutions to Climate Change, Part 1 After a review of the causes and effects of climate change, groups of students are challenged to brainstorm some ideas for slowing or stopping climate change, and lessening or reversing its effects.

3.11 Solutions to Climate Change, Part 2 Pairs of students choose several solutions from Climate Change Solution sheets to read and discuss. Students share solutions with each other, explaining how each solution addresses the causes or effects of climate change and reflect on whether they themselves might take some of these actions.

3.12 Thinking Critically about Climate Change Each pair of students creates a cause and effect flow chart predicting the effects of one possible solution to climate change. The class discusses a few of the flow charts, then each student writes their Revised Ideas, Part 2, summarizing what they have learned about the causes and effects of climate change.

Sample Opening Spread



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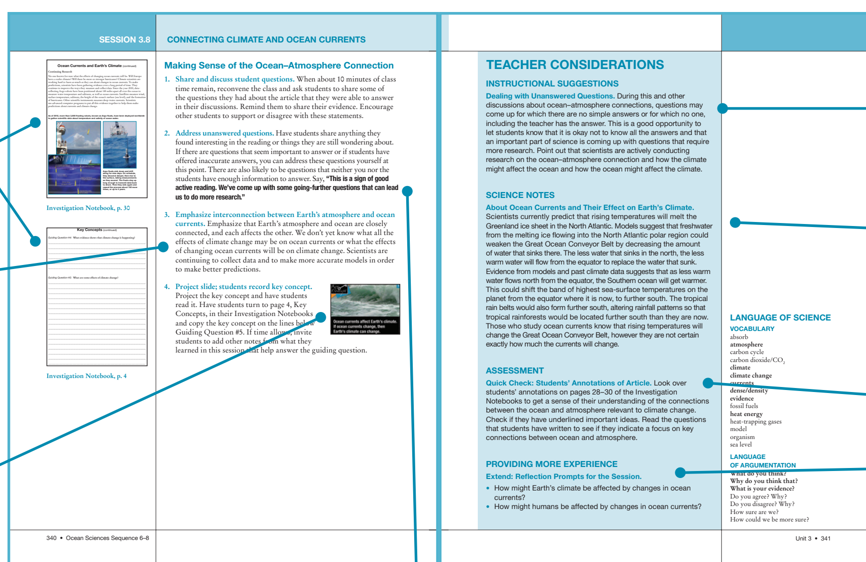

Session 1.2

Water vs. Air

Students learn that a scientific explanation is based on evidence. They predict what will happen when heat energy is added to bottles of water and air. Students observe as heat energy is added to the bottles and record data showing that water heats and cools much more slowly than air. Pairs draw molecules and try to use evidence to explain why this might be. A simulation and discussion introduce the concept that water acts as a heat reservoir. Student learning is focused on the following key concept:

- Water acts as a heat reservoir. Water absorbs a lot of heat energy before it warms up, and it holds onto the heat for a relatively long time before the heat energy is released and the water cools down.

Students also learn:

- Molecules in all substances move more when heat energy is added.
- Air warms up and cools down more quickly than water does.

Water vs. Air	Estimated Time
Introducing Evidence-Based Explanations	10 minutes
Investigating Water vs. Air	15 minutes
Drawing and Discussing Explanations	10 minutes
Making Sense of Results with the Simulation	10 minutes
Total	**45 minutes**

UNIT GOALS

SCIENCE CONTENT

- The Ocean as a Heat Reservoir
- Density and Movement of Ocean and Air Currents
- Water Cycle

PRACTICES OF SCIENCE

- Making explanations from evidence
- Using models

NATURE OF SCIENCE

- Scientific explanations are based on evidence
- Technology plays a role in gathering new evidence

SCIENCE LANGUAGE

- Using science vocabulary
- Having evidence-based discussions

Ocean Literacy Scope and Sequence and Climate Literacy Principle Correlations

Ocean Literacy S&S 6.A. The ocean absorbs and releases heat from the Sun, as well as distributes heat around the globe, thus moderating the temperature of Earth.

Climate Literacy Principle 1.A. The Sun is the primary source of energy for Earth's climate system.

WHAT YOU NEED

For the class:
- ❏ 2 1-liter clear bottles with caps*
- ❏ 1 clamp lamp with 72-watt incandescent lightbulb
- ❏ 2 bookends
- ❏ 2 thermometers
- ❏ 2 6-inch pieces of string
- ❏ scissors*
- ❏ timer or clock/watch with second hand*
- ❏ water*
- ❏ projection system*
- ❏ computer with Internet connection* or resource disc
- ❏ 2 slides for Session 1.2
- ❏ simulation, *Heat Reservoirs*
- ❏ 3 sheets of chart paper
- ❏ masking tape
- ❏ permanent marker
- ❏ (optional) document camera*
- ❏ (optional) Copymaster Packet

For each student:
- ❏ Investigation Notebook: pages 5, 10–12; optional page 9 (DWR)
- ❏ (optional) Copymaster Packet: Water vs. Air

*not provided in kit

GETTING READY

Before the day of the session:

1. **Set up projection system/review multimedia.** Set up and test the projection system to be sure all students will be able to see items projected during the session. Spend a few minutes reviewing this session's materials and supplemental resources found at mare.lawrencehallofscience.org/oss68 or by following the links (eBook) or using the resource disc (print version).
2. **Preview simulation.** Project and preview *Heat Reservoirs* until you are comfortable adding/taking away heat.
3. **Prepare bottles.** Fill one bottle completely with tap water and let it sit overnight or at least a few hours to assure it is at room temperature. Make sure the second bottle is completely dry and filled with air. Tie a piece of string to each thermometer and tape the other end of the string inside each bottle cap. Suspend one thermometer in each bottle and screw on the bottle caps.
4. **Set up lamp.** Place the lamp about 2 inches away from the bottles so that heat from the lamp will affect each bottle equally.
5. **(optional) Set up document camera.** If you are using a document camera, set it up so the lamp is behind the bottles and the document camera is facing the numbered sides of the thermometers. Twist each bottle so students will be able to see the thermometer reading that will be projected on the screen. Play with the classroom lights to get the best view of the numbers. Don't leave the lamp on for long, and turn it off well before class so the bottle of air has time to cool back down to room temperature. (The bottle of water won't increase in temperature unless you keep the light on for quite a while.)
6. **Make charts.** Make the following charts on sheets of chart paper:
   - Scientific Evidence (See Figure 1–2 on page 22.) Post it where it can stay up throughout the unit.
   - Water vs. Air Temperature Data (See Figure 1–3 on page 25.) Include only the title, column, and row headings; fill in your own data during the session.
   - (optional) Water vs. Air Temperature Line Graph (See Figure 1–4 on page 27.)

LANGUAGE OF SCIENCE

VOCABULARY
absorb
atmosphere
climate
condense/condensation
currents
dense/density
evaporate/evaporation
evidence
heat energy
heat reservoir
matter
model
molecule
precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION
What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

Next Generation Science Standards (NGSS) Correlations
Available online: www.mare.lawrencehallofscience.org/oss68

Introducing Evidence-Based Explanations

1. **Review water bottle investigation from Session 1.1.** Ask, **"In the last session, what happened to the water in the bottle when heat energy was added?"** List students' answers on the board. For each response ask, **"How do you know?"** and record that next to their responses.

What happened to the water?	How do you know? (evidence)
The water got warmer.	The temperature on the thermometer went up.
The water expanded.	We saw the water level in the bottle go up, and water came out the top.
The water molecules move faster and get farther apart.	We saw a simulation showing scientists' understanding of heat energy and molecules.

2. **Define *evidence*.** Tell students that evidence is a clue that helps answer a question or explain something. Write "evidence" underneath "How do you know?" in the column heading and tell students that the things they listed below are examples of evidence. Evidence can be data, observations, science knowledge, or reasoning.

TEACHER CONSIDERATIONS

DAILY WRITTEN REFLECTION

Daily Written Reflections are optional prompts that you can use to jump-start each session. You can have students write their responses or use the prompt for a class discussion or as homework. Prompts may encourage students to reflect on something they've learned or activate prior knowledge about what they will learn. Prompts provide students with opportunities to use science vocabulary, to make connections, and to clarify their thinking. Each prompt appears in the Investigation Notebook and includes lines for writing, as well as a space to draw. Tell students that for this kind of writing, it's more important to write their ideas than to have perfect spelling. These reflections are meant to be brief—give students about 5–10 minutes to respond. **Note:** This time has not been included in the overall session time frame.

What happens to water molecules when heat energy is added to them? Explain how you know. This prompt, found on page 9 of the Investigation Notebook, asks students to describe in their own words what happens to molecules when they are heated. Students may describe that molecules move faster and bang into each other with more force, as well as explaining that the spaces between molecules expand. Asking students to explain how they know is a precursor to learning more about using evidence in explanations in this session.

PROVIDING MORE EXPERIENCE

Reinforce: Review Investigation from Session 1.1. It may be helpful before starting this session to either describe or show students the investigation setup from the previous session. This will help them as they engage in a review of the results and later to emphasize the differences between the investigations in Session 1.1 and 1.2. Session 1.1 used one bottle filled with water, capped by a rubber stopper with a hole in it so the water inside could expand out the top. Session 1.2 uses two bottles, one filled with air and the other with water; both are tightly capped so nothing can escape. In both sessions, a lamp adds heat energy to the substances in the bottles.

SCIENCE NOTES

About Evidence in Science. The concept of evidence and the idea that scientists must base their explanations on evidence are central to this unit—and to science itself. Take every opportunity to reinforce this idea and encourage your students to frame their discussions in terms of evidence. Make sure students know that evidence observed directly through investigations, from books, or through their own reasoning will support their statements. Help frame responses by modeling the phrases, **"I think this because…"** or **"My evidence is…."**

LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
climate
condense/condensation
currents
dense/density
evaporate/evaporation
evidence
heat energy
heat reservoir
matter
model
molecule
precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION

What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

3. **Introduce Scientific Evidence chart.** Point to the chart you posted earlier and go over the different kinds of evidence:

Scientific Evidence

Evidence is a clue that helps answer a question or explain something.

Evidence can come from…

- our own investigations.
- other people's investigations.
- reasoning, thinking, and discussing.

Scientific explanations are based on evidence.

Figure 1–2.

- **Evidence from our own investigations.** Use an example of firsthand evidence from the water bottle investigation: When students saw the temperature change on the thermometer, that was evidence that the water got warmer. Seeing the water level go up was firsthand evidence that the water expanded.
- **Evidence from other people's investigations.** Watching a simulation about molecules is an example of evidence we got from other scientists. We can also find evidence by reading about other people's investigations and talking with others.
- **Evidence from reasoning, thinking, and discussing.** Sometimes evidence can come from thinking and talking about experiences you had in the past. For example, when students discussed how molecules expanded, they reasoned that the water expanded (increased in volume) and could no longer fit in the bottle.
- **Scientific explanations are based on evidence.** Explain that a good scientific explanation puts together evidence in a way that answers a question and provides reasons for the answer. Tell students that they will have many chances to make scientific explanations in this unit.

Investigating Water vs. Air

1. **Introduce Water vs. Air investigation.** Tell students that today's investigation will use two tightly sealed bottles; one filled with water and one containing air. The investigation will start with both bottles at room temperature. A lamp will provide heat energy to both bottles. The class will record the temperature of each bottle every few minutes.

TEACHER CONSIDERATIONS

PROVIDING MORE EXPERIENCE

Prepare: Gases Have Mass. Some students may not be fully convinced that air (a mixture of gases) has mass and therefore may mistakenly think the air bottle is empty. It's important for students to be aware that the bottle is not empty, even though the gases inside can't be seen. This misconception will be addressed more fully later in the unit. Describe the following piece of evidence that air has mass and is something, not nothing: when you fill a balloon with air, the balloon gets bigger. Ask students for other pieces of evidence. [You can feel air on your skin when wind blows or when you move your hand quickly through the air; parachutes catch air to slow a fall; people need to breathe air, and our chest and lungs expand when we take it in.]

ENGLISH LANGUAGE LEARNERS

Adjust Teacher Talk. This session includes both a fairly complex explanation of an investigation as well as in-depth class discussions. Adjusting teacher talk can help ELLs understand explanations and make sense of and participate in class discussions. One adjustment you can make is to indicate visual references, such as the materials used in the investigation or simple drawings on the board.

INSTRUCTIONAL SUGGESTIONS

Small Group Investigations. You may decide to have students do the "Investigating Water vs. Air" activity in small groups rather than doing it as a teacher demonstration. Many have found this to be an effective presentation option if access to additional materials is not a problem. If you decide to set this up for small groups, you will need to gather the following materials for each group: 2 thermometers, 2 pieces of string, 2 clear plastic 1-liter bottles with caps, desk or heat lamp, and a means to direct the heat at the bottle. We have provided an optional student sheet with directions and a place to record data in the Copymaster Packet.

LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
climate
condense/condensation
currents
dense/density
evaporate/evaporation
evidence
heat energy
heat reservoir
matter
model
molecule
precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION

What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

Water vs. Air Temperature Data

Time at Start	Air (°C)	Water (°C)

Lamp ON

Time	Air (°C)	Water (°C)

Lamp OFF

Time	Air (°C)	Water (°C)

Investigation Notebook, p. 10

2. **Turn and Talk to make predictions.** Remind pairs of the Turn and Talk routine. Emphasize that they should use evidence to back up their ideas about the following questions and to ask their partners for evidence if they don't share it:
   - **What will happen to the temperature of the two bottles receiving heat energy?**
   - **Which bottle do you predict will heat up faster?**

3. **Circulate during Turn and Talk.** Remind partners to use evidence and to be ready to change their predictions if they hear new evidence. Encourage everyone to listen quietly and to be polite if they disagree.

4. **Share predictions with class.** After a few minutes, lead a whole-group discussion and have a few volunteers share their predictions about which bottle will heat up faster. Encourage them to share their evidence and reasoning, and ask other students to respond.

5. **Introduce temperature data chart.** Show students the Water vs. Air Temperature Data chart on the wall (Figure 1–3), and have a volunteer check the starting temperature in each bottle. Have the volunteer record the temperatures and time on the chart. Make sure students realize that the starting temperatures of the water and air are the same. Tell students that you will call on volunteers to read the temperatures and record on the wall chart every minute for five minutes.

6. **Record data in Investigation Notebooks.** Distribute Investigation Notebooks and have students turn to page 10, Water vs. Air Temperature Data, which they will see is very similar to the chart on the wall. Have students record the starting time (0 minutes) and both temperatures.

7. **Turn lamp on for 5 minutes and discuss in pairs.** While the lamp is on, have students record the times and temperatures each minute as volunteers record them on the class chart. In pairs, have students discuss whether the air or the water is heating up faster.

8. **Turn off the lamp after five minutes.** After a volunteer records the last Lamp ON temperature reading, turn off the lamp. Leave the bottles where they are so that you yourself can check and continue to record the temperatures on the data chart as they cool (see Figure 1–3, Lamp OFF).

TEACHER CONSIDERATIONS

Water vs. Air Temperature Data			
	Time	Air (°C)	Water (°C)
START	0 min.	21.7	21.7
Lamp ON	1 min.	23.1	21.7
	2 min.	26.0	21.7
	3 min.	30.0	21.7
	4 min.	33.0	22.0
	5 min.	35.0	22.0
Lamp OFF	2 min.	29.5	22.0
	4 min.	27.0	22.0
	6 min.	25.5	22.0
	8 min.	23.8	22.0
	10 min.	22.5	22.0

Figure 1–3. This class chart is an example of data collected during the investigation. Your data may be different, but you can expect a similar overall pattern. The bottle of air will increase and decrease in temperature rapidly, while the bottle of water may change only a little, or not at all in this period of time.

ASSESSMENT

Quick Check for Understanding: Discussion Skills during Turn and Talk. Listen during Turn and Talk to assess students' discussion skills—listening carefully and respectfully disagreeing with their partners. You will also want to note whether students are referring to evidence in order to back up their predictions. This will be an important skill developed throughout this unit. Sometimes you may want to have your students quickly write notes about their ideas before sharing.

LANGUAGE OF SCIENCE

VOCABULARY

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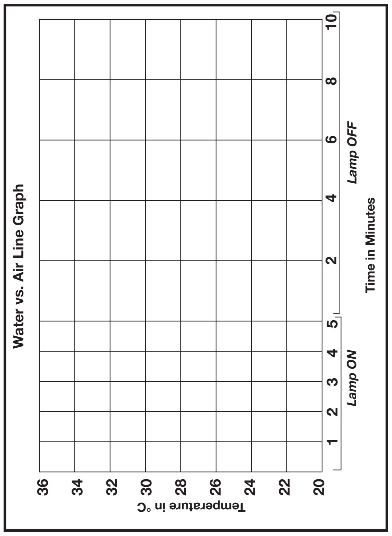
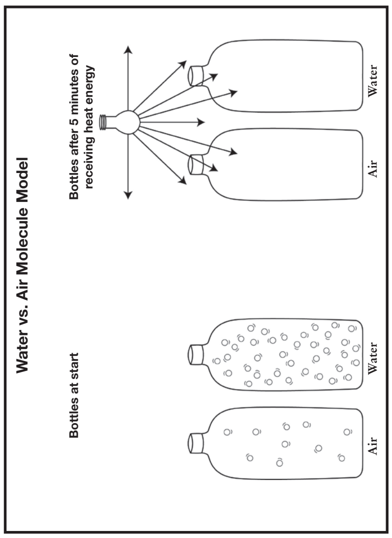
molecule
precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION

What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?



Investigation Notebook, p. 11

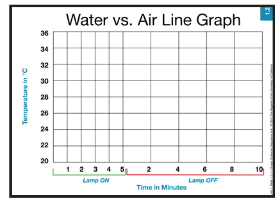


Investigation Notebook, p. 12

Drawing and Discussing Explanations

1. **Ask what happened to the temperatures.** Remind students that the temperatures listed on the chart are evidence they can use to explain something. Based on this evidence, have students compare what happened to the water and air in the two bottles. [The air heated up much faster and reached a higher temperature than the water.]

2. **Display line graph slide; record lamp ON temperatures.** Tell students that it isn't always easy to discern patterns from a data chart such as the one they are using, but putting the data into a line graph can help make the patterns more obvious. Direct students to the line graph template on page 11 of their Investigation Notebooks, Water vs. Air Line Graph. Project the slide image to show students where to add the temperature data in degrees centigrade on the *y* axis and time in minutes on the *x* axis. Instruct students to complete the graph, using the Lamp ON-data that they recorded on the facing page. Tell students that the class will add additional data to the graph as the bottles cool and also discuss what the line graph reveals in a few minutes.



3. **Record lamp OFF data.** Tell students that as they work on their line graphs and discuss, you will check the temperatures of the two bottles and record the data on the class chart every two minutes. They can also record this data on the chart in their Investigation Notebooks, and then add it to their line graphs.

4. **Explain Water vs. Air Investigation Notebook page.** Have students turn to Investigation Notebook page 12, Water vs. Air Molecule Model. Tell them the drawing of two bottles on the left side of the page represents the water and air bottles before the lamp was turned on. As in the last session, the black circles represent molecules, and the lines represent movement. More lines mean more movement.

5. **Note differences between air and water.** Ask, **"On this page, what differences do you notice between the molecules in the water bottle and the molecules in the air bottle?"** [The air molecules are farther apart.] Explain that scientists have observed that air molecules are farther apart than water molecules at the same temperature.

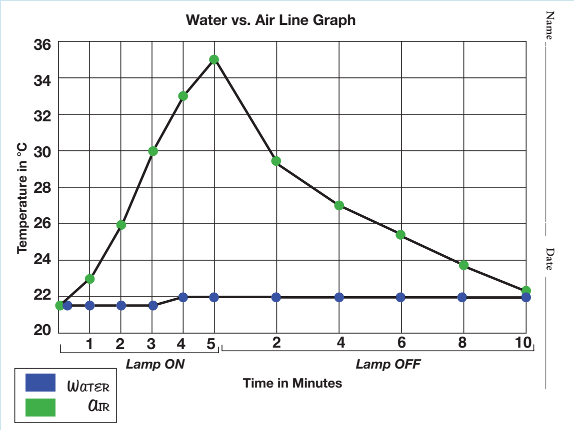
6. **Give draw and discuss instructions.** Tell students that scientists often make drawings to show their ideas. In this activity, students will first work individually to make a drawing in the notebook that shows their ideas. Next, each student will share and discuss their drawing with a partner. Students may change their drawings if they hear more compelling evidence from their partners. If a pair of students finishes before time is called, they should join with another pair and explain their drawings to one another.

TEACHER CONSIDERATIONS

PROVIDING MORE EXPERIENCE

Prepare: Constructing Line Graphs. Depending on your students' experience with constructing line graphs, you may want to provide additional directions or guidance. If your students have little experience with this form of graphing, or you are short on time, you could skip making the line graph, or perhaps show them a completed graph and focus on the evidence provided by the results.

Figure 1–4. Guide students to plot the data points for Lamp ON and draw connecting lines, then label the lines. Follow the same procedure once you have data for Lamp OFF. Note that at the beginning, the air and water temperature data points start from the same place.



PROVIDING MORE EXPERIENCE

Prepare: Centigrade vs. Fahrenheit. Depending on the experience of your students with measuring temperature using centigrade units, you may want to provide a quick review to compare temperatures in centigrade and fahrenheit:

100°C	=	212°F	=	boiling temperature of water
0°C	=	32°F	=	freezing temperature of water
21.1–22.2°C	=	70–72°F	=	average room temperature

INSTRUCTIONAL RATIONALE

Benefits of Draw and Discuss Activity. In this activity, students draw their ideas individually, then describe and explain what they drew to a partner. If a pair of students finishes before time is called, they join with another pair and explain their drawings to one another. In this way, students have the opportunity to use multiple modalities (listening, drawing, and discussing with peers) to make sense of ideas. As partners describe their ideas and drawings, they practice citing evidence and becoming more open to changing their minds if they hear more compelling evidence.

LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
climate
condense/condensation
currents
dense/density
evaporate/evaporation
evidence
heat energy
heat reservoir
matter
model
molecule
precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION

What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

7. **Draw and Discuss.** Explain that the two bottles on the right side of the notebook page represent the air and water bottles after receiving heat energy for five minutes. Each student will draw molecules inside these bottles on page 12, then explain to their partners why they think the air warmed up more and faster than the water. To show movement, have students draw small lines around the molecules. As in the last session, more lines mean more movement, and if they need to show very large motions, they can draw arrows. As students draw, then discuss, continue to check the temperatures of the air and water bottles and record the time and temperatures on the class chart.

8. **Class discusses results.** Regain the attention of the class and call on volunteers to share their explanations. Ask, **"What makes you think that?" "What is your evidence?"** If possible, show some of students' drawings using a document camera.

9. **Complete line graphs and discuss.** Have students look at the data you added to the chart after the lamp was turned off and complete their line graphs. [The air bottle temperature will have dropped rapidly and the water bottle will stay relatively the same.] Invite students to explain why they think the air cools faster than the water.

Making Sense of Results With the Simulation

1. **Molecules in all substances move more with heat energy.** Confirm that when heat energy is added to water, air, or any substance, the molecules move more and get farther apart. This is thermal expansion. More molecule movement means the substance gets hotter. If students haven't mentioned it, point out that in the bottles, the molecules could not expand much because the bottles are sealed.

2. **Project simulation.** Orient students to the starting screen of Heat Reservoirs where the air and water molecules are at 26°C (close to room temperature). Mention that this simulation is based on scientific evidence about how molecules move. Ask, **"What do you notice?"** [Students may say the air molecules move around in the bottle more than water molecules, and there are more water molecules than air molecules.] Ask, **"Does the air or the water have more matter in it?"** Emphasize that there is more matter (more molecules) in the bottle with water than in the bottle with air even though the size of the bottles are the same same.

3. **Add heat energy.** Click "HEAT ON" to show what happens to the water and air molecules with heat energy added. Ask, **"What do you notice?"** [The air molecules move faster and go farther than the water molecules.] Tell students that temperature is a measure of how much the molecules are moving. The less the molecules move, the lower the temperature will be. As students watch the simulation, ask them to describe what they observe and to contrast air and water.

TEACHER CONSIDERATIONS

INSTRUCTIONAL RATIONALE

Why Hold Off Explaining Why Air Cools Faster than Water? Use the class discussion after the Draw and Discuss activity as an opportunity for students to discuss their ideas so far. As students engage with the simulation in the next part of the session, the phenomenon will be more fully explained, so they can make sense of the results.

SCIENCE NOTES

How Thermometers Work. As the temperature increases, the alcohol or mercury inside the tube expands, forcing itself up the narrow tube. As the liquid cools, there is less energy in the molecules so when they collide they do not travel as far apart from one another. The molecules move less far apart, so the volume of the liquid decreases, causing the liquid in the tube to go back down the tube.

Why Water Doesn't Change Temperature Easily. Water has a high specific heat which means a lot of heat energy must be absorbed or lost before it will change temperature. The main reason for its high specific heat is the kind of bond that holds multiple water molecules together. These hydrogen bonds between water molecules can absorb a lot of heat energy before they break. Once the bonds connecting multiple water molecules break, the independent water molecules start to move faster, resulting in an increase in temperature. (Specific heat is the amount of heat that must be absorbed or lost for one gram of a substance to change its temperature by one degree Celsius).

What Happens to the Air and Water Molecules When the Heat is Turned Off? When the heat is turned off, there is less energy in the molecules so as they collide with one another, they do not travel as far apart. The molecules appear to get closer together. A more accurate way to describe what happens to the molecules is that they "move less far apart" rather than they get closer together. However it is described, what can be observed is that the molecules appear to get closer together.

INSTRUCTIONAL SUGGESTIONS

Size of Water Molecules. You might want to point out that the water molecules look like they are different sizes. This is to represent that some are close (larger), and some are farther away (smaller).

LANGUAGE OF SCIENCE

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LANGUAGE OF ARGUMENTATION

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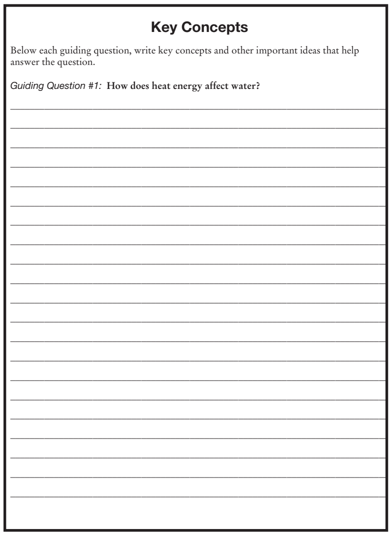

Key Concepts

Below each guiding question, write key concepts and other important ideas that help answer the question.

Guiding Question #1: How does heat energy affect water?

Investigation Notebook, p. 5

4. **Debrief why water heated up more slowly than air.** Ask, **"Why did the water heat up more slowly than the air?"** If students don't say it themselves, explain that one reason is because there is more matter in water to heat up. The more "stuff" or matter there is, the more heat energy it takes to get all the molecules to move more.

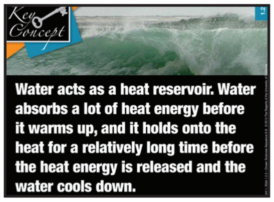
5. **Introduce the term *absorb*.** Write "absorb" on the board and say, **"*Absorb* means to take in. Another reason water heats up more slowly than air is that water molecules can absorb a lot of heat energy before they start moving more."**

6. **Let air and water cool.** At the end of 5 minutes, click "HEAT OFF." The timer will run as the bottles cool. After students have had a chance to watch, say, **"Describe what happens to the air and water molecules when the heat is turned off."** [The molecules slow down and appear to get closer together.] **"Which cooled off more quickly?"** [Air.]

7. **Summarize results of cooling containers.** Emphasize that once the lamp was turned off, the water lost heat energy very slowly, while the air quickly lost heat energy.

8. **Introduce the term *heat reservoir*.** Write "heat reservoir" on the board and explain that a reservoir is like a lake where water is stored. The word *reservoir* can also be used to describe other things that are stored up, such as heat energy stored in water. Explain that we can think of water as a reservoir—heat is put in, saved up, and then given out again slowly. This is why scientists call water a *heat reservoir*.

9. **Project slide; students record key concept.** Project the key concept and have students read it. Have students turn to page 5, Key Concepts, in their Investigation Notebooks, and copy the key concept on the lines below the first guiding question on the page. Emphasize that water is an unusual substance and that almost no other substance acts as a heat reservoir as well as water does. If time allows, invite students to add other notes from what they learned in this session that help answer this guiding question.



TEACHER CONSIDERATIONS

PROVIDING MORE EXPERIENCE

Reinforce: Pairs or Small Groups Explore the Simulation. If you have access to computers for every pair or small group of students, and if time allows, give students the opportunity to explore the Heat Reservoir simulation independently.

Extend: Reflection Prompts for the Session.

- The ocean is the largest heat reservoir on the planet. How do you think the ocean as a heat reservoir affects the planet?
- How have your ideas about molecules changed today? Start by completing the sentence: I used to think molecules ________ , but now I know ________ .
  Add several sentences to give more details.

LANGUAGE OF SCIENCE

VOCABULARY

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heat energy
heat reservoir
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model
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precipitation
water cycle
water vapor

LANGUAGE OF ARGUMENTATION

What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

GEMS®

OCEAN SCIENCES SEQUENCE:
The Ocean–Atmosphere Connection and Climate Change

Investigation Notebook

Unit 1:
How Do the Ocean and Atmosphere Interact?

Name ______________________________ Date ____________________

Daily Written Reflection

What happens to water molecules when heat energy is added to them? Explain how you know.

____

____

____

____

____

____

____

____

____

____

____

____

Make a drawing if it helps you explain. Label your drawing.

Name ________________________________ Date ____________________

Water vs. Air Temperature Data

Time at Start	Air (°C)	Water (°C)

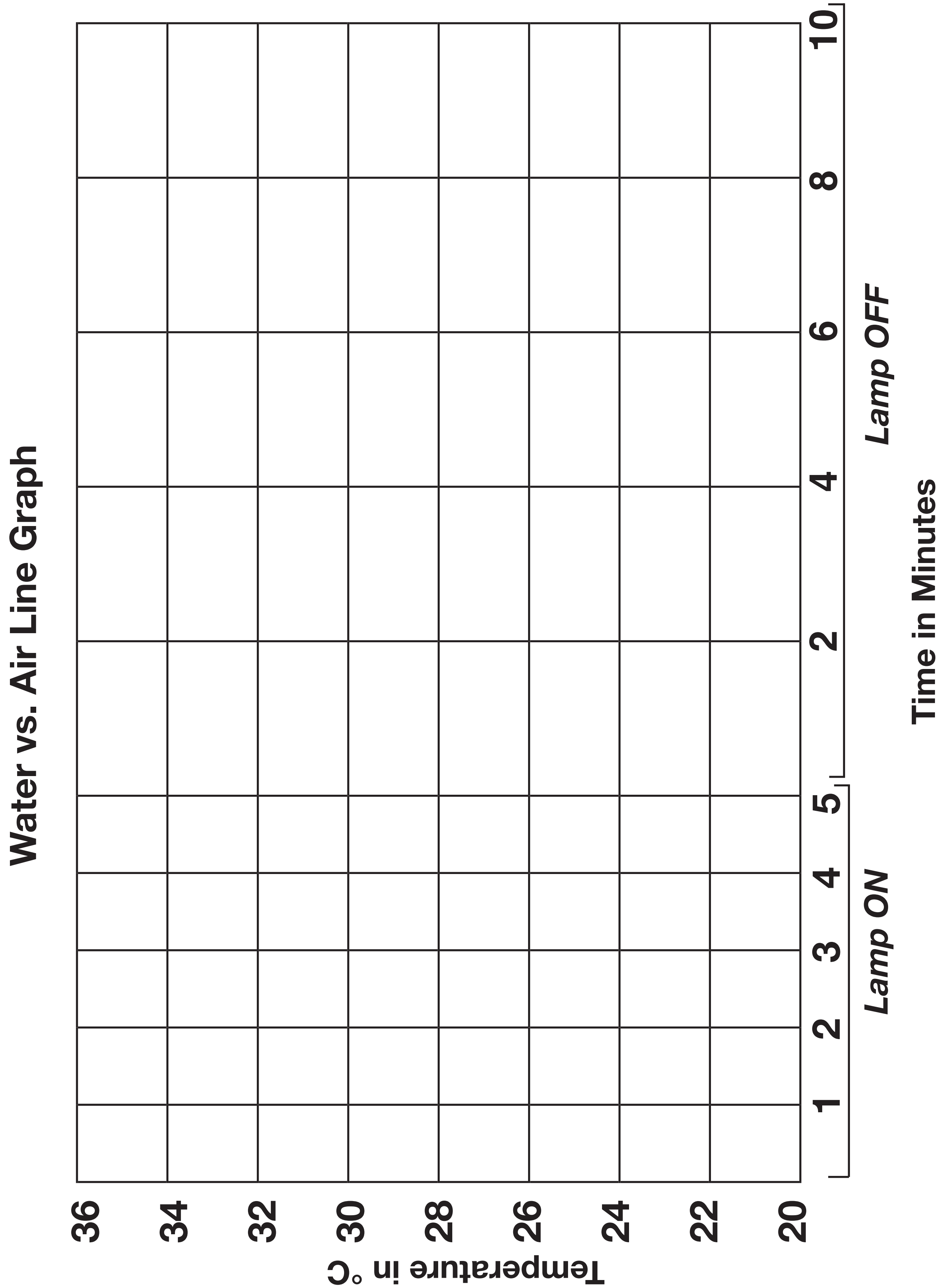
Lamp ON

Time	Air (°C)	Water (°C)

Lamp OFF

Time	Air (°C)	Water (°C)

Name ________________________________ Date ____________________

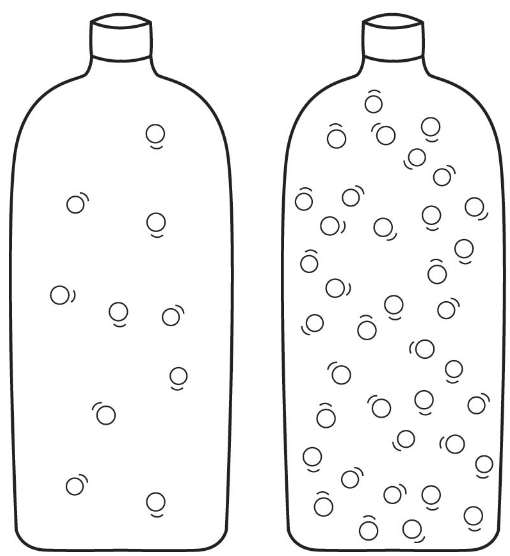


Water vs. Air Line Graph
Temperature in °C
36
34
32
30
28
26
24
22
20
1
2
3
4
5
Lamp ON
2
4
6
8
10
Lamp OFF
Time in Minutes

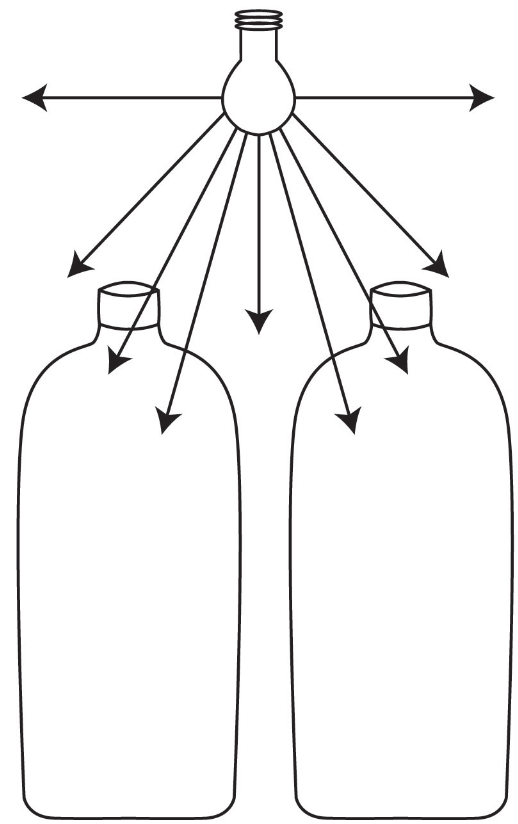
Name ______________________ Date ______________

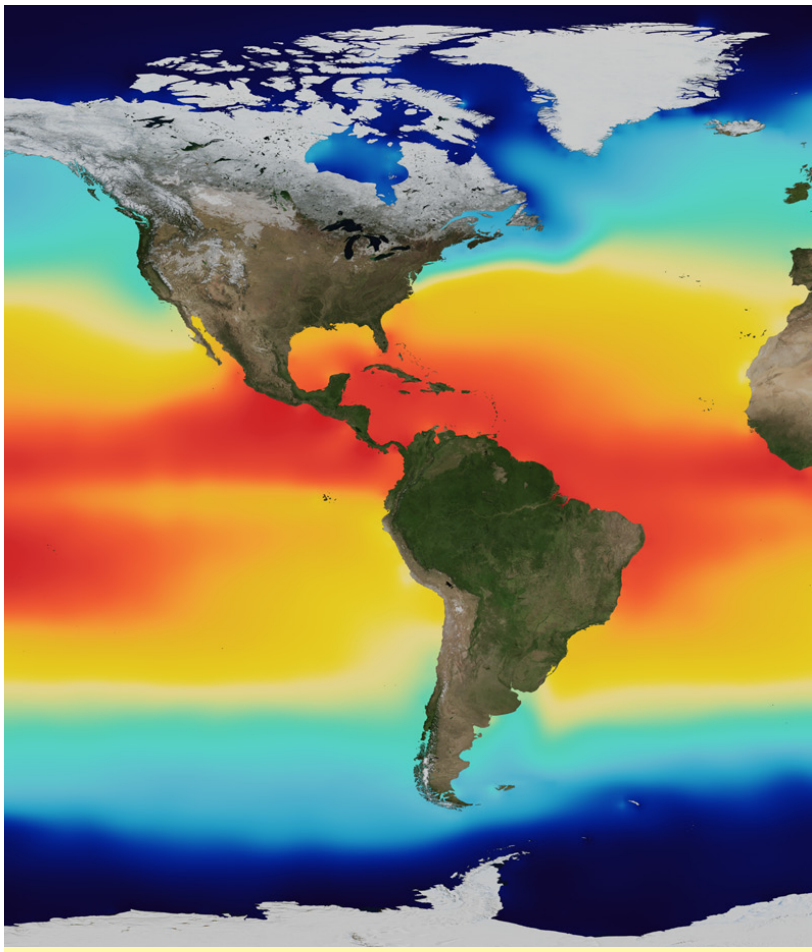
Water vs. Air Molecule Model

Bottles at start



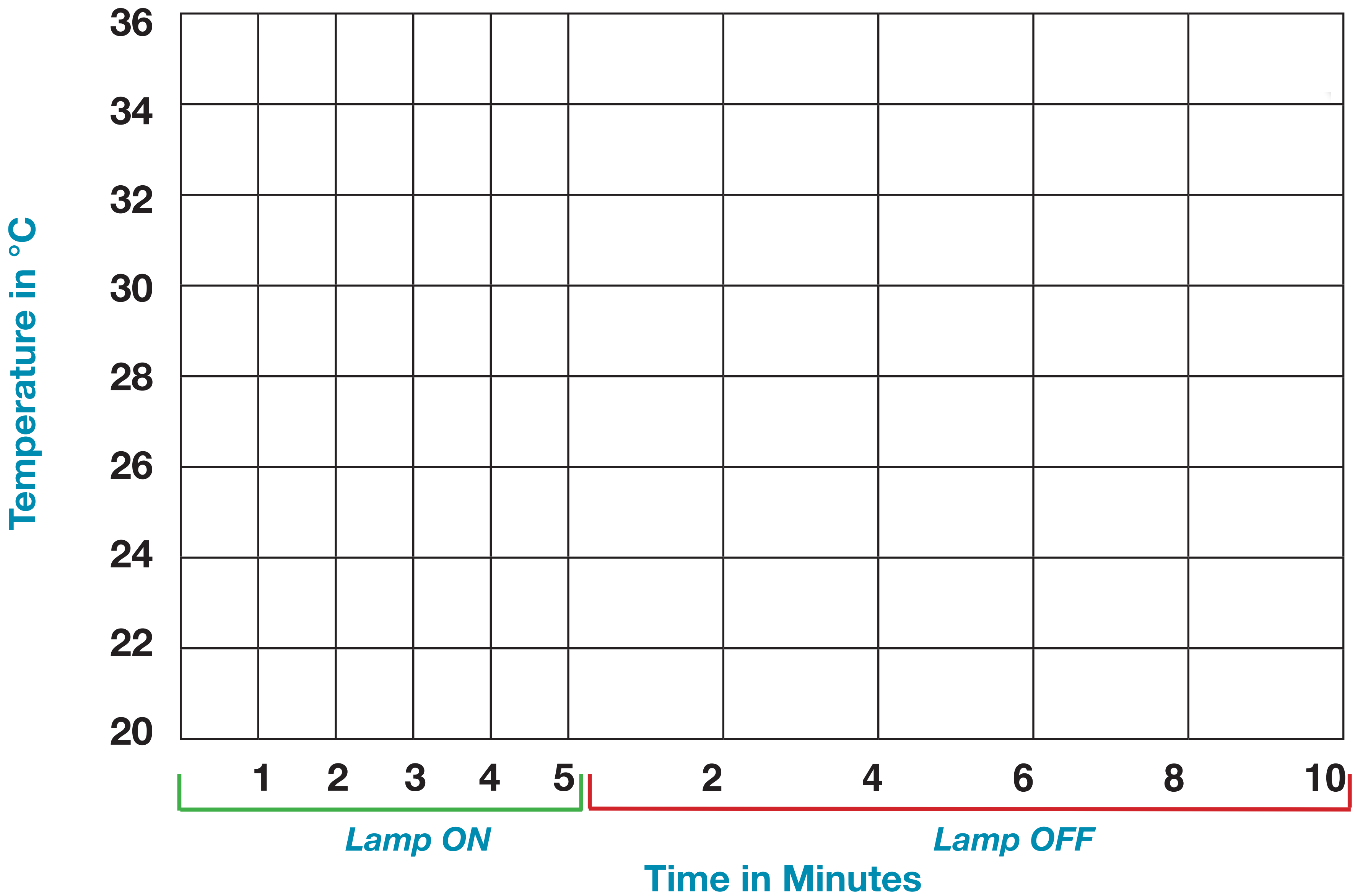
Bottles after 5 minutes of receiving heat energy





Interested in purchasing or implementing?
contact gems@berkeley.edu

Water vs. Air Line Graph



Water acts as a heat reservoir. Water absorbs a lot of heat energy before it warms up, and it holds onto the heat for a relatively long time before the heat energy is released and the water cools down.