UNIT 2

Atmosphere and Climate

Activity 2: Using Climate Proxies

The Table of Contents for this unit is shown in regular type while the information for the other units is grayed out. Because this unit represents only part of the full book, there are gaps in the sequence of page numbers. The Table of Contents, Glossary, and the Index correctly refer to the page numbers within this unit but also include references to pages not included in this unit.

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less complete records show processes that affect climate over longer periods, and indicate how much climate has changed.

LITERACY SUPPLEMENT 6.2
Responses to *Three-Level Reading Guide* for "Evidence of Earth's Past"

1. *Are these statements correct? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

Y a. Natural records of past climate, such as tree rings and coral growth, can tell us what it was like hundreds and even thousands of years ago.

N b. ~~Tree rings can be used to tell what the climate was like hundreds of thousands of years ago.~~ *Tree rings can be used to tell what the climate was like for the past few hundred years. Some long-lived species (e.g., redwoods) can provide information for one or two thousand years but are unreliable past that.*

Y c. Bubbles of trapped air in ice can be analyzed to tell us concentrations of greenhouse gases in the atmosphere at the time the ice formed.

2. *Do you think these statements agree with the reading? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

Y a. It is possible to determine what the climate was like in the past, although the further back in time we go, the more uncertain we are of our determinations.

Y b. If data obtained from different methods agree, for example ice core and tree ring data, then we feel more confident in our determination of what the climate was like in years past.

3. *Do you agree with these statements and can you find evidence—in the reading or elsewhere—to support your position? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

Y a. Although data from analysis of rocks is less detailed than that from tree rings, it is nevertheless valuable in determining what Earth's climate was like in the past.

Y b. Climate proxies, such as tree rings and ice cores are more reliable than human written records in general because people can make mistakes.

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2. Each of the climate proxies discussed in the reading yields information about climate in a particular area of Earth—land or sea, tropical, temperate, or arctic areas. Why would it be important to have data from all these different areas?
3. Some climate records, such as tree rings, give more detailed and continuous information about past climate, but only date back hundreds or thousands of years. Other climate records, such as those in continental rocks, go back much farther but are less complete or detailed. How might scientists use each of these types of information to learn about how Earth's climate system works?

ACTIVITY 2
Using Climate Proxies

Setting the Stage: Using Forams as Clues to Ocean Temperature

As you learned in the reading *Evidence of Earth's Past*, scientists are able to use various clues preserved in ocean sediment to learn about Earth's climate history. The microscopic foraminifera *Neogloboquadrina pachyderma* (*N. pachyderma*) serves as a particularly useful indicator of ocean temperature. These foraminifera (Figure 6.10) are found in two forms. When the ocean water is relatively warm, this organism tends to grow into a right-coiling form. When the water is relatively cold, *N. pachyderma* grows into a left-coiling form. When these organisms die, they settle to the ocean bottom and their skeletons are incorporated into the accumulating layers of sediment, preserving a record of the ocean temperature at the time each organism was alive.

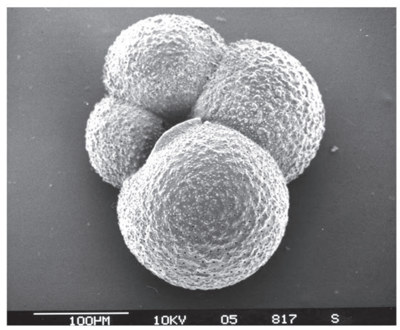

FIGURE 6.10
Neogloboquadrina pachyderma *is a microscopic organism that provides valuable clues about past ocean temperature.*

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ACTIVITY 2
Using Climate Proxies

In this activity, students simulate using evidence from ocean sediment cores to determine past climates.

Facilitating *Activity* 2—"Using Climate Proxies"

Prior to class:

- Post a table at the front of the classroom for students to use when recording their group's data. (See the Materials and Preparations section for the setup of this table.)

During class:

- Have students work with a partner on this activity.
- Review the procedures with the students and discuss what the sample bags represent. Remind them that in real life these foraminifera are so small that they would need to do the counting under a microscope. Also remind them that in actual sediment cores, there would likely be a number of different types of organisms other than *Neogloboquadrina pachyderma*.

- Make sure all teams record their data on the class chart, and then copy the class data into their notebook, filling in student Table 6.2.
- Have students answer the Analysis questions and prepare for a discussion.

Responses to *Analysis* for Activity 2—"Using Climate Proxies"

1. Describe your results:
   a. During what time periods was the ocean water relatively warm according to the simulated foraminifera data? *The water was relatively warm between 75,000 and 125,000 years ago and for the last 10,000 years.*
   b. During what time periods was the ocean water relatively cold according to the simulated foraminifera data? *The ocean water was relatively cold between 20,000 and 60,000 years ago and 140,000 and 200,000 years ago.*
2. Relate the ocean water temperature recorded in these sediment samples to past global climate. What does it tell you? What does it not tell you about global climate at the time these layers formed? *Students may say that these data tell you what ocean temperatures were like at the location where the sediment accumulated, and this is likely to correlate with atmospheric temperatures in that region as well. The data do not necessarily tell you what ocean and atmospheric temperatures were in other parts of the world. Additional data from different regions would need to be collected to develop a more global picture. These data also do not tell us about other aspects of the climate, such as precipitation.*

CHAPTER 6 • THE LONGEST EXPERIMENT: CLIMATE CHANGE IN EARTH'S HISTORY

Scientists study the record preserved in the sediment layers by drilling into the ocean bottom using a variety of coring devices. They obtain undisturbed sediment cores using hollow tubes, such as the one shown in Figure 6.11. The sediment cores are then brought to the surface and analyzed. The age of the layers is determined using radioisotopic dating techniques, and each layer is carefully studied.

In this activity, you will simulate counting and analyzing the number of right-coiling versus left-coiling *N. pachyderma* in the layers of a sediment core. You will use these data to determine past ocean temperatures.

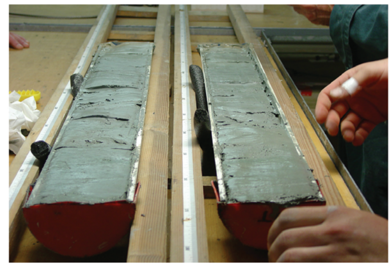

FIGURE 6.11
This sediment core from the ocean floor near New Zealand contains microscopic organisms, such as foraminifera, that can be used to determine past ocean temperatures. The core halves have been swiped with a spatula so that sedimentary features in the core can be seen.

Procedure

Record all observations and answers in your notebook as you work.

1. Carefully pour the contents of your core onto your desk or lab bench, being careful not to lose any pieces (this could cause errors in your measurements). Notice that there are three different fossil foraminifera (forams) as shown in Figure 6.12 below: left-coiling *N. pachyderma*, right-coiling *N. pachyderma*, and *Globigerinoides sacculifer (G. sacculifer)*:[3]

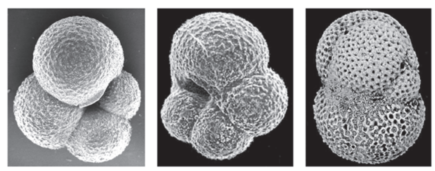

FIGURE 6.12
(left to right) left-coiling N. pachyderma, *right-coiling* N. pachyderma, *non-coiling* G. sacculifer

2. Count and record the number of each of the different types of forams found in your sediment core.
3. Note the age of your core sample (printed on your core tube) then record the number of right-coiling and left-coiling *N. pachyderma* in the row of the class chart that corresponds to the age of your core.
4. Make a table in your notebook similar to Table 6.2. Copy the class data into it.

Materials

FOR EACH TEAM OF STUDENTS
- "sediment core" containing "forams"
- tray
- calculator

FOR EACH STUDENT
- ruler (optional)
- graph paper

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Teaching Strategies

The radio-isotopic dating techniques referred to in the introduction to this activity are covered in Chapter 8. However, you could spend some time teaching about dating techniques at this point as well.

Teaching Strategies

To abbreviate this activity, you could simply pass out the data to students (number of right-coiling and left-coiling foraminifera at each age interval) and have them complete the table and graph.

3. Aside from the fact that you didn't use real organisms, describe your initial ideas about how this activity might be similar to and different from the real processes scientists follow to analyze sediment cores. *Answers will vary. Students may say that the actual foraminifera samples would be much smaller and would need to be counted under a microscope, there probably wouldn't be the same number in each core sample, and/or that there are likely to be other organisms and materials within the sample as well. They might realize that it would be more difficult to distinguish differences in the coiling direction of two similar foraminifera than it was for them to sort the images (and that it would have to be done very carefully to avoid errors in measurements). Students may propose that in an actual sample, some foraminifera would be broken into pieces, making it more difficult to count the individuals. They may also have found that counting the foraminifera was somewhat tedious. It is not the intention of this activity to convince students that scientific work is boring; however, they should realize this type of careful work is very much a part of science and provides the basic data necessary for discoveries.*

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5. For each time period in the chart, calculate the total number of *N. Pachyderma* and the percent of right-coiling *N. Pachyderma*. Record your results in Table 6.2.

Table 6.2

AGE (years ago)	RIGHT-COILING *N. PACHYDERMA*	LEFT-COILING *N. PACHYDERMA*	TOTAL NUMBER OF *N. PACHYDERMA*	% RIGHT COILING (WARM WATER)
0				
30,000				
60,000				
90,000				
120,000				
150,000				
180,000				
210,000				

6. Create a labeled line graph that shows the percent of right-coiling organisms versus time.
7. Since a higher percentage of right-coiling *N. Pachyderma* corresponds to warmer temperatures, label the warm and cool periods on your graph.
8. Write answers to the Analysis questions and be prepared to discuss them with the class.

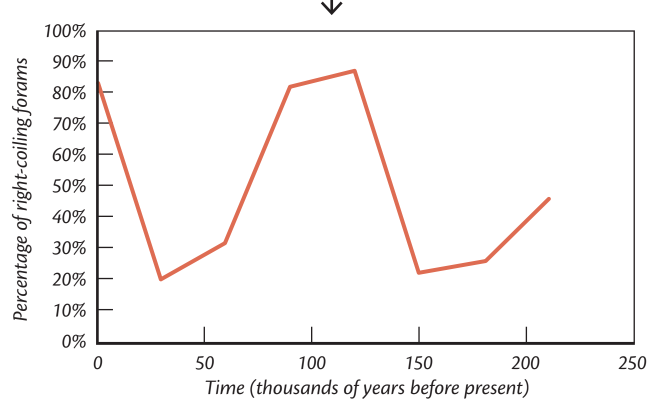
Analysis

With your group, complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. Describe your results:
   a. During what time periods was the ocean water relatively warm according to the simulated foraminifera data?
   b. During what time periods was the ocean water relatively cold according to the simulated foraminifera data?
2. Relate the ocean-water temperature recorded in these sediment samples to past global climate. What does it tell you? What does it not tell you about global climate at the time these layers formed?
3. Aside from the fact that you didn't use real organisms, describe your initial ideas about how this activity might be similar to and different

Student Answers for Table 6.2

AGE (YEARS AGO)	RIGHT-COILING N. PACHYDERMA	LEFT-COILING N. PACHYDERMA	TOTAL N. PACHYDERMA	% RIGHT-COILING N. PACHYDERMA
0	42	8	50	84%
30,000	10	40	50	20%
60,000	16	34	50	32%
90,000	41	9	50	82%
120,000	44	6	50	88%
150,000	11	39	50	22%
180,000	13	37	50	26%
210,000	23	27	50	46%



LITERACY SUPPLEMENT 6.2

Three-Level Reading Guide for "Evidence of Earth's Past"

1. *Do you think these statements agree with the reading? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

   _____ a. Natural records of past climate, such as tree rings and coral growth, can tell us what it was like hundreds and even thousands of years ago.

   _____ b. Tree rings can be used to tell what the climate was like hundreds of thousands of years ago.

   _____ c. Bubbles of trapped air in ice can be analyzed to tell us concentrations of greenhouse gases in the atmosphere at the time the ice formed.

2. *Do you think these statements agree with the reading? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

   _____ a. It is possible to determine what the climate was like in the past, although the further back in time we go, the more uncertain we are of our determinations.

   _____ b. If data obtained from different methods agree, for example ice core and tree ring data, then we feel more confident in our determination of what the climate was like in years past.

3. *Do you agree with these statements and can you find evidence—in the reading or elsewhere—to support your position? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*

   _____ a. Although data from analysis of rocks is less detailed than that from tree rings, it is nevertheless valuable in determining what Earth's climate was like in the past.

   _____ b. Climate proxies, such as tree rings and ice cores are more reliable than human written records in general because people can make mistakes.

CHAPTER SIX

The Longest Experiment: Climate Change in Earth's History

Overview

Scientists use sophisticated computer models to simulate the complex interactions between components of Earth's climate system. These models are critical to predictions about climate change that will happen in the coming decades. However, small changes in the assumptions that underlie these models can have a significant influence on what these models predict. How do scientists know how Earth will actually behave?

Earth's climate system has been operating for billions of years, and as it turns out, the climate has changed dramatically in the past. Earth's geologic record—in the form of ice, sediments, rocks, and fossils—is a treasure trove of information about climate change that has happened in the past and how these changes have affected the planet. Earth's climate system is very complex, and although scientists continue to improve their understanding of the different factors and feedbacks operating on different time and spatial scales, the information presented in this chapter is necessarily quite simplified. There are so many feedbacks within Earth's climate system that the absolute causes of climate change are uncertain. However, the data from the study of Earth's climate history are invaluable in improving the accuracy of global climate models and making better predictions about the future.

In this chapter, students explore climate change that has happened in Earth's past and think about its relevance to climate change happening now. They study data about changes currently happening related to Earth's climate and examine the forecasts of climate models about Earth's future. In addition to building on their foundation of knowledge about Earth's atmosphere and hydrosphere from previous chapters, this study connects them to many of the concepts covered later in the course, relating to plate tectonics and the rock cycle.

Goals for Student Understanding

This table shows alignment of *NGSS* core ideas,, practices of science and engineering, and crosscutting concepts with chapter learning objectives. This is not intended to be used as a checklist, but it shows how students' learning experiences in *EDC Earth Science* map to the *NGSS Standards*. This chapter supports students working towards HS-ESS2-4, HS-ESS3-5.

NGSS Overview

Learning Objective	NGSS Core Ideas, Practices, and Crosscutting Concepts	Where Taught
Students understand that Earth's climate has changed dramatically in the past.	ESS2.D Asking questions Developing and using models Constructing explanations Patterns Cause and effect Systems and system models Scale, proportion, and quantity Energy and matter Stability and change	*What's the Story?*—"Journey to a Different Time" *Activity 3*—"Investigating How Orbital Changes Have Affected Past Climate" *Reading*—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age" "How Fast Can the Climate Change?
Students know that scientists investigate Earth's climate history by studying records of past climates stored in tree rings, coral, rocks, sediment, and ice, as well as more recent human records of weather data.	ESS2.D Analyzing and interpreting data Using mathematics Constructing Explanations Engaging in Argument from Evidence Patterns Cause and effect Stability and change	*Activity 2*—"Using Climate Proxies" *Activity 4*—"What's Happening Now and What's Predicted for the Future?" *Reading*—"Evidence of Earth's Past"
Students know that periodic changes in the tilt of Earth as well as its orbit have caused changes in the distribution of solar input, which has affected global climate in the past.	ESS1.B, ESS2.D Developing and using models Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Activity 3*—"How Orbital Changes have Affected Past Climate"
Students know that historical fluctuations in global average temperature have corresponded with fluctuations in atmospheric CO_2 levels, related to factors such as the movement of tectonic plates over millions of years.	ESS2.A, ESS2.D Analyzing and interpreting data Constructing explanations Engaging in argument from evidence Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Readings*— "The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age" "How Fast Can the Climate Change?" "Sorting Out Natural and Human-induced Climate Change"
Global climate models predict that temperatures will continue to rise, and that the amount of temperature change predicted is related to future CO_2 emissions. These temperature increases are already causing sea level rise, the melting of glacial and polar ice, and changes in precipitation and ocean acidity. Students know that CO_2 increases over the past 100 years are largely attributable to human activities.	ESS2.D, ESS3.D Analyzing and interpreting data Using mathematics Using Models Engaging in Argument from Evidence Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Activity 4*—"What's happening now and what's projected for the future?" *Reading*—"What's Happening Now and What's Predicted for the Future?"

Possible Misconceptions and Barriers to Learning

- The concepts covered in this chapter are sophisticated and will challenge students to use all the skills they have acquired during this course. Many students are likely to still have difficulties with visualizing Earth's processes in three dimensions and understanding that small, incremental changes over millions of years can have dramatic effects. They also are likely to continue to struggle with conceptualizing complex, dynamic systems involving multiple interacting factors. Be aware of these challenges as you listen to students during class discussions and review their work.
- Many people have the idea that during the Pleistocene the temperatures were constantly below freezing and don't understand that there were periods during which the climate was as warm as today. The Ice Age was actually a period of climate instability with dramatic fluctuations in temperature. The Pleistocene has included about 20 glacial intervals and 20 interglacial intervals. Scientists think that Earth's climate is in an interglacial interval today.

Assessment Outcomes

Students should be able to

1. give examples of how Earth's climate has changed in the past.
2. describe how climate proxies are used by scientists to investigate Earth's climate history.
3. model how periodic changes in Earth's orbit, called Milankovitch cycles, triggered the advance and retreat of continental ice sheets during the Pleistocene.
4. explain and give an example of how increased rates of volcanism associated with plate tectonic movements may have caused increased levels of atmospheric CO_2 and climate change in the past.
5. explain and give an example of how mountain-building associated with collisions between two plates can decrease atmospheric CO_2 levels and cause global cooling.
6. describe how certain changes in Earth's systems such as sudden changes in ocean circulation, can cause more rapid climate change.
7. relate the predictions of global climate models to CO_2 emissions, and to data regarding changes in precipitation, ocean acidity, arctic ice extent, glacier volume, and sea-level rise.
8. describe evidence that human activities have increased CO_2 concentrations in the atmosphere and caused the increased global temperatures measured over the last century.

Assessment Strategies

Students have a number of opportunities in this chapter to express their initial and developing understanding of concepts related to the processes that cause Earth's climate to change. By taking note of the answers given by students completing group work or working individually, you can determine pacing, identify which concepts need more or less emphasis, and gauge students' understanding of the content at the end of the chapter. The following table summarizes the formative and summative assessment opportunities.

The table also provides an alignment between the student assessment outcomes and the assessment items at the end of the chapter. You should determine ahead of time which of these assessment opportunities you will evaluate formally (assign a grade) and which you will evaluate more informally. In general, the *Consider* and *Investigate* sections provide opportunities for formative assessment, and the *Process* section provides opportunities for summative assessment.

Assessment Overview

Opportunities	Information Gathered
Consider	
Brainstorming	Students' prior understandings of Earth's history and initial ideas about what could have caused climate to be different in the past
What's the Story—"Journey to a Different Time"	Students' initial understandings of the types of evidence used to reconstruct Earth's climate history, and review of how changes in Earth's energy balance can affect global temperature Assessment Outcome 1 (Assessment items 7, 8)
Investigate	
Activity 1—"Looking for Clues to the Past"	Assessment Outcome 2 (Assessment items 1–3)
Reading—"Evidence of Earth's Past"	Assessment Outcome 2 (Assessment items 1–3)
Activity 2—"Using Climate Proxies"	Assessment Outcome 2 (Assessment items 1–3)
Activity 3—"Investigating How Orbital Changes Have Affected Past Climate"	Assessment Outcome 3 (Assessment items 4, 5)
Reading—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age"	Assessment Outcomes 4, 5 (Assessment item 6)
Reading—"How Fast Can the Climate Change?"	Assessment Outcome 6 (Assessment item 9)
Activity 4—"What's Happening Now and What's Projected for the Future?"	Assessment Outcome 7 (Procedure Part A, Steps 2, 3; Part B, Steps 1–3; Analysis Questions 1–5)
Reading—"Sorting Out Natural and Human-induced Climate Change"	Assessment Outcome 8 (Assessment item 7)
Address the Challenge	Students' abilities to synthesize what they have learned from their study of Earth's climate history and teach it to others through a museum exhibit
Process	
Share	Students' understandings of the key concepts covered in this chapter
Discuss	Students' ideas about how their thoughts about climate have changed since the beginning of this unit, and their abilities to synthesize what they have learned, relating phrases and terms used in this chapter to the concept of climate change
Assessment	Students' understandings of the range of concepts presented throughout the chapter; these questions can be used in class, for homework, or as a quiz at the end of the chapter.

Scope and Sequence

The following is provided to help with your lesson planning. Adjust it according to the needs and interests of your classroom, and whether you assign readings as homework or complete them in class.

WEEK			DAY		PREVIEW
1	**Consider**		1	Introduce chapter and discuss *Brainstorming* questions	Students brainstorm what they know about Earth's history—in particular, the Cretaceous Period in which dinosaurs lived and the Pleistocene Ice Age. They think about how climate could have been so much colder during the Pleistocene and about ways that studying climate change in Earth's history could help humans better understand climate change that is happening now.
			2	Read/discuss *What's the Story*—"Journey to a Different Time" Introduce *Challenge*	Students read a story about a very warm point in Earth's history when no polar ice caps existed and a very cold point in Earth's history when ice covered much of North America. They think about what might have caused Earth's climate to change so dramatically in the past and what might cause the climate to change now and in the future.
	Investigate	Gather Knowledge	3	*Activity 1*—"Looking for Clues to the Past"	Students practice looking for evidence of events that have happened in the past by looking for clues around the classroom.
			4	*Reading*— "Evidence of Earth's Past"	Students read about climate proxies—tools used by scientists to investigate Earth's climate history. They summarize what they have learned and think about the importance of collecting climate proxy data from different locations around Earth.
			5	*Activity 2*—"Using Climate Proxies"	Students use simulated proxy data from sediment cores to determine past ocean temperatures.
2			6	*Activity 3*—"Investigating How Orbital Changes Have Affected Past Climate"	Students use a model Earth and Sun to demonstrate the Milankovitch cycles and think about how these orbital cycles affect the intensity of Earth's seasons and in turn the advance and retreat of ice sheets during the Pleistocene.
			7	*Reading*—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Cretaceous"	Students read about how plate tectonic movements occurring over very long periods of time have led to warm and cool periods in Earth's history. They think about how climate change in the past is relevant to Earth's future.
			8	*Reading*—"How Fast Can the Climate Change?"	Students read about abrupt climate change events that have occurred in Earth's history and the potential causes of these events.
			9	*Activity 4*—"What's Happening Now and What's Projected for the Future," Part A	Students study the predictions of global climate models and relate them to observed changes in global temperature, sea-level rise, ice measurements, ocean acidification and precipitation.
			10	*Activity 4*—"What's Happening Now and What's Projected for the Future," Part B	
3		Address the Challenge	11	*Reading*—"Sorting Out Natural and Human-Induced Climate Change	Students read about how scientists use their understanding of Earth's climate history to assess whether climate change happening now is due to natural processes or human activities. They summarize evidence that human activities are contributing to the current warming trend.
			12	*Address the Challenge:* Create Museum Exhibit	Students prepare museum exhibits that explain the key concepts they studied in this chapter.
	Process		13	*Share* exhibits	Students share their museum exhibits and review the major concepts covered in this chapter.
			14	*Discuss* concept mapping	Students discuss how their ideas about climate have changed since the beginning of the unit and review the complex factors that can bring about climate change by creating a concept map that relates the various terms and phrases used in this chapter.
	Review		15	Review	
	Assessment		16	Summative Assessment	

Materials and Preparation

Note: All reproducible pages (Student Sheets, Literacy Supplements, and Resource Supplements) and many images from the student book can be found in the Teacher Resources as PDFs or slide presentations.

You may choose to use the following optional Literacy Supplements:

- Literacy Supplement 6.1: *Anticipation Guide* for "Journey to a Different Time"
- Literacy Supplement 6.2: *Three-Level Reading Guide* for "Evidence of Earth's Past"
- Literacy Supplement 6.3: *Three-Level Reading Guide* for "The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age"
- Literacy Supplement 6.4: *Science Fact Triangle* for "How Fast Can the Climate Change?"
- Literacy Supplement 6.5: *Science Fact Triangle* for "Sorting Out Natural and Human-Induced Climate Change"

You may want to place a poster with a geologic timeline on the wall to refer to during this chapter.

Prior to *Activity* 2—"Using Climate Proxies"

1. Gather the materials listed below.

FOR THE TEACHER
- gravel, "foram" sheets, and 16 plastic "sediment core" tubes (*see* Step 2 below)

FOR EACH TEAM OF STUDENTS
- 1 "sediment core" (containing gravel and "forams") (*see* Step 2 below)
- 1 tray (for sorting contents of "sediment core")
- 1 calculator*

FOR EACH STUDENT
- (optional) ruler
- graph paper*

*not included in LAB-AIDS equipment package

Foram Counts for Activity 2

AGE (YBP=years before present)	FORAM COLOR	FORAM TYPE		
		RIGHT COILING	LEFT COILING	OTHER
0 ybp (today)	dark blue	42	8	25
30,000 ybp	yellow	10	40	25
60,000 ybp	gray	16	34	25
90,000 ybp	green	41	9	25
120,000 ybp	orange	44	6	25
150,000 ybp	light blue	11	39	25
180,000 ybp	brown	13	37	25
210,000 ybp	pink	23	27	25

2. Check the number of "forams" in each plastic "sediment core" tube (see Foram Counts table). There should be one striped set and one solid set for each age. Sort them if they are mixed. For first-time use, remove forams from sheets and place each set in one tube, along with about 200 cm^3 of gravel.

3. Create a class data table similar to the Foram Counts table. Post it so teams can record their data.

Prior to *Activity* 3—"Investigating How Orbital Changes Have Affected Past Climate"

1. Gather the materials listed below.

FOR EACH TEAM OF STUDENTS
- 1 plastic "planet" with wooden axis (*see* Step 2 below)
- access to a light source*
- marker

*not included in LAB-AIDS equipment package

2. If needed, assemble the "plastic planets" by connecting the two halves and inserting a wooden dowel for the axis.

Prior to *Activity* 4—"What's Happening Now and What's Projected for the Future"

1. Gather the materials listed below.

PART A—FOR EACH STUDENT
- (optional) ruler
- graph paper*

PART B—FOR THE CLASS
- 2 sets Expert Group 1 Data Cards (Figs. 6.20, 6.21 in student book)
- 2 sets Expert Group 2 Data Cards (Figs 6.22, 6.23 in student book)
- 2 Expert Group 3 Data Cards (Fig. 6.24 in student book)
- 2 sets Expert Group 4 Data Cards (Figs. 6.25, 6.26 in student book)
- means of projecting Expert Group Data Cards* (see Step 2 below)

*not included in LAB-AIDS equipment package

2. Projectable Expert Group Data Card images are in the Chapter 6 slide presentation in Teacher Resources.

Prior to *Address the Challenge*

1. Gather materials for students to use to create visuals for their museum exhibits.

Prior to *Process*

1. Optional Resource Supplement 6.1: *Climate Change Concept Map* is available in Teacher Resources or the Chapter 6 slide presentation.

2. You may want to invite another class or community members to view students' museum exhibits.

EDC EARTH SCIENCE: AN OVERVIEW

EDC Earth Science is a full-year, activity-driven high school earth science course developed with support from the National Science Foundation, and aligned to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (the *Framework*) (National Research Council [NRC], 2012) and the *Next Generation Science Standards* (Lead States, 2013). The course involves students by challenging them with provocative investigations and questions. EDC Earth Science has been designed in the belief that students are capable of rigorous and in-depth explorations in science when given adequate support, structure, and motivation for learning.

Highlights of *EDC Earth Science*

EDC Earth Science stresses the following goals:

- In-depth understanding of content, based on recommendations in national and representative state frameworks.
- Preparing students for subsequent advanced courses through developmentally appropriate treatments of earth science concepts that build on previous learning.
- Developing students' reading, writing, data analysis, and communication skills to produce science-literate citizens.
- Motivating students to acquire the knowledge for solving a problem, by offering them historical, newsworthy, and fictionalized stories that draw them into the earth science content.
- Teaching students to tackle problems and challenges in science by using accurate information, critical thinking, and problem solving to reach decisions grounded in evidence and logic.
- Offering varied learning strategies and activities that help students construct meaning from their experiences and that serve as bridges between concrete and abstract thinking.

Each chapter of *EDC Earth Science* offers a cluster of activities that addresses a specific set of concepts and practices and is centered on a challenge that embodies the learning goals. The amount of class time for each chapter varies from one to four weeks of classroom sessions. The challenges focus on real, relevant, and often complex problems that scientific information and data analyses can help resolve. For example, in Chapter 11, students are challenged to consider the advisability of building a new town on the flanks of Mount Rainier. To gather the information necessary to address this challenge, students explore the nature of subduction zones and their relationship to plate tectonics while learning basic volcanology. They also analyze authentic scientific monitoring data and individually draw evidence-based conclusions about the level of risk associated with living near a Cascades volcano. Engagement in resolving the chapter's challenges teaches and reinforces certain basic habits of mind central to the work of earth scientists (Kastens et. al., 2009). These are:

- Scientists' thinking is grounded in, motivated by, or tested against observations.
- Scientists draw heavily on spatial and temporal reasoning.
- Scientists expect things to be complicated.
- Scientists use multiple modes of inquiry.
- Many claims in science are based on the preponderance of the evidence from multiple lines of data-based reasoning.
- Scientists collaborate.
- Scientists look for evidence globally.
- Scientists pool their data.
- Scientists think with and communicate with many kinds of representations, such as models, and data visualizations.

Spotlight on Components

The main components of the curriculum are the teacher edition and the student edition (designed to be used together).

Teacher Edition. The teacher edition is your starting point for *EDC Earth Science* and your daily road map for instruction. Please use the teacher edition as you plan for and teach the curriculum. All the essentials of your lesson plans are available in each of the chapters. You will find:

- Step-by-step information about the teaching sequence and ways to facilitate the challenges, readings, and class discussions.
- An overview, learning goals, assessment outcomes and strategies, and discussion of students' misconceptions and possible barriers to understanding.

- A list of materials, advance preparation information, science background, and answers to questions in the student edition.

Student Edition. The student edition includes the activities and readings for each chapter, as well as discussion questions and analyses to be completed by students. This book

- helps students connect their prior knowledge to the new material.
- presents narrative readings ("the stories") that highlight earth science at play in the world around them, prepare students to study those earth science phenomena, and create a need to know.
- poses challenges and provides guidance for pursuing those challenges.
- presents questions that help students gauge, solidify, and extend their understanding throughout each chapter.
- provides activities that engage students in observing, experimenting, interpreting data, and modeling scientific phenomena.
- provides science content readings that augment and solidify understanding.
- supplies performance and written assessment materials.

Equipment Kits. *EDC Earth Science* contains more than 60 hands-on activities to develop students' core earth science content knowledge and skills. Students may carry out some activities using local equipment, but EDC has developed and field-tested many activities with equipment designed by Lab-Aids, the program publisher. Contact Lab-Aids at www.lab-aids.com for a complete description of equipment and materials available for the *EDC Earth Science* program.

Online Teaching Resources. A full suite of ancillary teaching resources is provided on the Lab-Aids Online Portal and via the *EDC Earth Science* page on the Lab-Aids website. These include links to real-time data, animations and supplemental information, slide presentations to go with each chapter, supplemental readings, student notebook sheets, literacy supplements such as anticipation guides to go with each reading, and a complement of test bank items.

For more information, see https://www.lab-aids.com/login.

Spotlight on Content

Each of the 17 chapters in this course addresses a specific set of concepts. Chapters build on prior knowledge, progressing from the simple to the more complex, and from the concrete to the abstract. This scaffolding of learning permits the exploration of earth science concepts at increasingly greater depth in a gradual, step-by-step fashion. While the course was written as a full-year sequence, it is also available as individual units.

The following charts provide a quick picture of the chapter sequence for this course. For comprehensive descriptions, please refer to the beginning of each chapter in your teacher edition.

Format and Features

The following sample pages show key elements of the format and features of the teacher edition. With the exception of the mid-year and final course challenges (Chapters 7 and 17), all of the chapters follow the same design. In particular, please note these features:

- Goals for students' understanding, with links to *Next Generation Science Standards* core ideas, practices, and crosscutting concepts
- Dealing with students' misconceptions
- Student assessment outcomes and strategies
- Scope and sequence
- Materials and preparation
- The learning cycle
- Teaching instructions
- Sample class data or expected results
- Answers to analysis questions and literacy supplements
- Careers in the earth sciences
- Chapter review

CHAPTER SIX

The Longest Experiment: Climate Change in Earth's History

Overview

Scientists use sophisticated computer models to simulate the complex interactions between components of Earth's climate system. These models are critical to predictions about climate change that will happen in the coming decades. However, small changes in the assumptions that underlie these models can have a significant influence on what these models predict. How do scientists know how Earth will actually behave?

Earth's climate system has been operating for billions of years, and as it turns out, the climate has changed dramatically in the past. Earth's geologic record—in the form of ice, sediments, rocks, and fossils—is a treasure trove of information about climate change that has happened in the past and how these changes have affected the planet. Earth's climate system is very complex, and although scientists continue to improve their understanding of the different factors and feedbacks operating on different time and spatial scales, the information presented in this chapter is necessarily quite simplified. There are so many feedbacks within Earth's climate system that the absolute causes of climate change are uncertain. However, the data from the study of Earth's climate history are invaluable in improving the accuracy of global climate models and making better predictions about the future.

In this chapter, students explore climate change that has happened in Earth's past and think about its relevance to climate change happening now. They study data about changes currently happening related to Earth's climate and examine the forecasts of climate models about Earth's future. In addition to building on their foundation of knowledge about Earth's atmosphere and hydrosphere from previous chapters, this study connects them to many of the concepts covered later in the course, relating to plate tectonics and the rock cycle.

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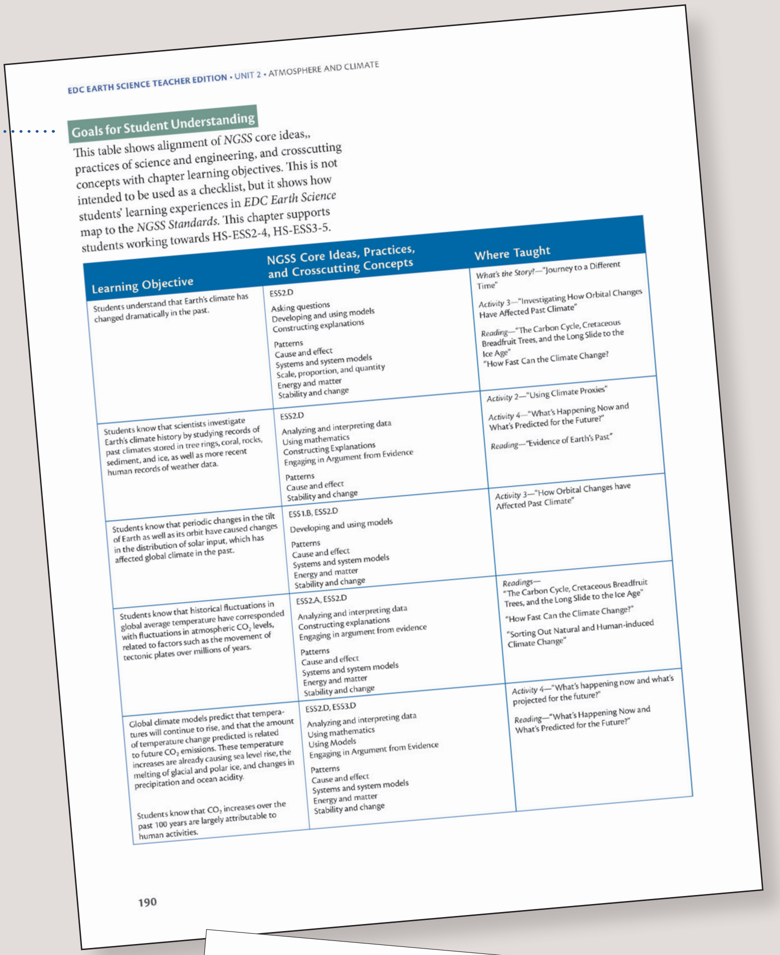
Each chapter begins with an overview of the chapter content, connecting it to earlier and later chapters.

Chapter content and activities are explicitly linked to the NGSS core ideas, practices, and crosscutting concepts.

Alignment with the *Standards* ensures that students are developing the knowledge and skills outlined in the NGSS performance expectations.



EDC EARTH SCIENCE TEACHER EDITION • UNIT 2 • ATMOSPHERE AND CLIMATE

Goals for Student Understanding

This table shows alignment of *NGSS* core ideas,, practices of science and engineering, and crosscutting concepts with chapter learning objectives. This is not intended to be used as a checklist, but it shows how students' learning experiences in *EDC Earth Science* map to the *NGSS Standards*. This chapter supports students working towards HS-ESS2-4, HS-ESS3-5.

Learning Objective	NGSS Core Ideas, Practices, and Crosscutting Concepts	Where Taught
Students understand that Earth's climate has changed dramatically in the past.	ESS2.D Asking questions Developing and using models Constructing explanations Patterns Cause and effect Systems and system models Scale, proportion, and quantity Energy and matter Stability and change	*What's the Story?*—"Journey to a Different Time" *Activity 3*—"Investigating How Orbital Changes Have Affected Past Climate" *Reading*—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age" "How Fast Can the Climate Change?
Students know that scientists investigate Earth's climate history by studying records of past climates stored in tree rings, coral, rocks, sediment, and ice, as well as more recent human records of weather data.	ESS2.D Analyzing and interpreting data Using mathematics Constructing Explanations Engaging in Argument from Evidence Patterns Cause and effect Stability and change	*Activity 2*—"Using Climate Proxies" *Activity 4*—"What's Happening Now and What's Predicted for the Future?" *Reading*—"Evidence of Earth's Past"
Students know that periodic changes in the tilt of Earth as well as its orbit have caused changes in the distribution of solar input, which has affected global climate in the past.	ESS1.B, ESS2.D Developing and using models Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Activity 3*—"How Orbital Changes have Affected Past Climate"
Students know that historical fluctuations in global average temperature have corresponded with fluctuations in atmospheric CO_2 levels, related to factors such as the movement of tectonic plates over millions of years.	ESS2.A, ESS2.D Analyzing and interpreting data Constructing explanations Engaging in argument from evidence Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Readings*— "The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age" "How Fast Can the Climate Change?" "Sorting Out Natural and Human-induced Climate Change"
Global climate models predict that temperatures will continue to rise, and that the amount of temperature change predicted is related to future CO_2 emissions. These temperature increases are already causing sea level rise, the melting of glacial and polar ice, and changes in precipitation and ocean acidity. Students know that CO_2 increases over the past 100 years are largely attributable to human activities.	ESS2.D, ESS3.D Analyzing and interpreting data Using mathematics Using Models Engaging in Argument from Evidence Patterns Cause and effect Systems and system models Energy and matter Stability and change	*Activity 4*—"What's happening now and what's projected for the future?" *Reading*—"What's Happening Now and What's Predicted for the Future?"

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Teachers are alerted to possible misconceptions and how to deal with them in class.

Student assessment outcomes and strategies are clearly defined.

CHAPTER 6 • THE LONGEST EXPERIMENT: CLIMATE CHANGE IN EARTH'S HISTORY

Possible Misconceptions and Barriers to Learning

- The concepts covered in this chapter are sophisticated and will challenge students to use all the skills they have acquired during this course. Many students are likely to still have difficulties with visualizing Earth's processes in three dimensions and understanding that small, incremental changes over millions of years can have dramatic effects. They also are likely to continue to struggle with conceptualizing complex, dynamic systems involving multiple interacting factors. Be aware of these challenges as you listen to students during class discussions and review their work.
- Many people have the idea that during the Pleistocene the temperatures were constantly below freezing and don't understand that there were periods during which the climate was as warm as today. The Ice Age was actually a period of climate instability with dramatic fluctuations in temperature. The Pleistocene has included about 20 glacial intervals and 20 interglacial intervals. Scientists think that Earth's climate is in an interglacial interval today.

Assessment Outcomes

Students should be able to

1. give examples of how Earth's climate has changed in the past.
2. describe how climate proxies are used by scientists to investigate Earth's climate history.
3. model how periodic changes in Earth's orbit, called Milankovitch cycles, triggered the advance and retreat of continental ice sheets during the Pleistocene.
4. explain and give an example of how increased rates of volcanism associated with plate tectonic movements may have caused increased levels of atmospheric CO_2 and global warming in the past.
5. explain and give an example of how mountain-building associated with collisions between two plates can decrease atmospheric CO_2 levels and cause global cooling.
6. describe how certain changes in Earth's systems such as sudden changes in ocean circulation, can cause more rapid climate change.
7. relate the predictions of global climate models to CO_2 emissions, and to data regarding changes in precipitation, ocean acidity, arctic ice extent, glacier volume, and sea-level rise.
8. describe evidence that human activities have increased CO_2 concentrations in the atmosphere and caused the increased global temperatures measured over the last century.

Assessment Strategies

Students have a number of opportunities in this chapter to express their initial and developing understanding of concepts related to the processes that cause Earth's climate to change. By taking note of the answers given by students completing group work or working individually, you can determine pacing, identify which concepts need more or less emphasis, and gauge students' understanding of the content at the end of the chapter. The following table summarizes the formative and summative assessment opportunities.

The table also provides an alignment between the student assessment outcomes and the assessment items at the end of the chapter. You should determine ahead of time which of these assessment opportunities you will evaluate formally (assign a grade) and which you will evaluate more informally. In general, the *Consider* and *Investigate* sections provide opportunities for formative assessment, and the *Process* section provides opportunities for summative assessment.

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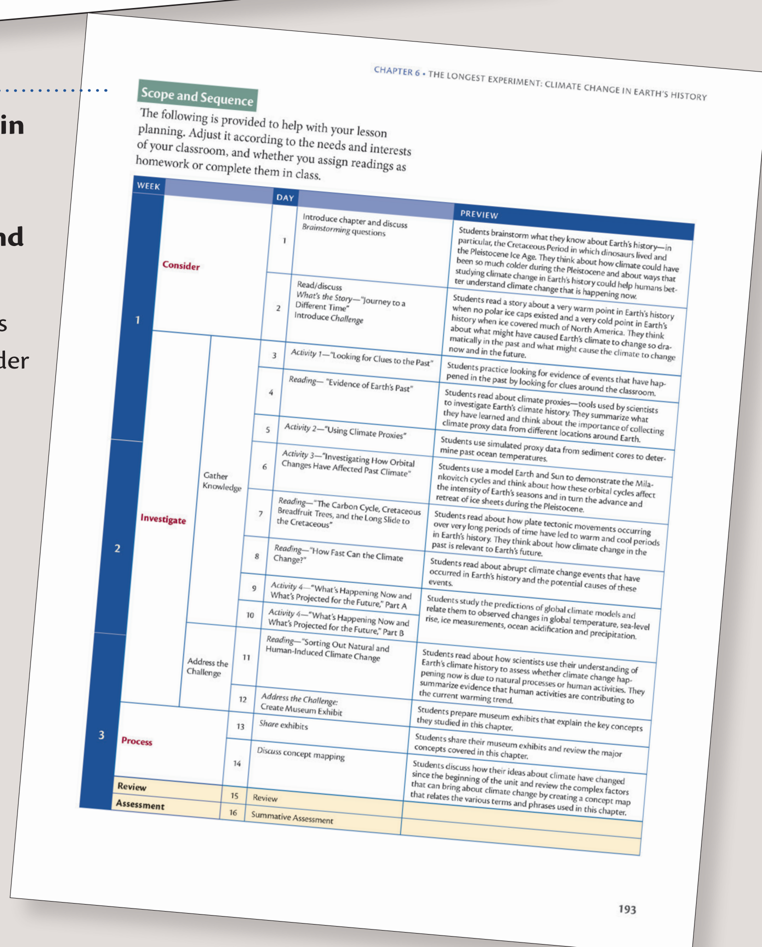
The link between activity, assessment outcome, and end-of-chapter questions is clearly marked.

Opportunities	Information Gathered
Consider	
Brainstorming	Students' prior understandings of Earth's history and initial ideas about what could have caused climate to be different in the past
What's the Story—"Journey to a Different Time"	Students' initial understandings of the types of evidence used to reconstruct Earth's climate history, and review of how changes in Earth's energy balance can affect global temperature Assessment Outcome 1 (Assessment items 7, 8)
Investigate	
Activity 1—"Looking for Clues to the Past"	Assessment Outcome 2 (Assessment items 1–3)
Reading—"Evidence of Earth's Past"	Assessment Outcome 2 (Assessment items 1–3)
Activity 2—"Using Climate Proxies"	Assessment Outcome 2 (Assessment items 1–3)
Activity 3—"Investigating How Orbital Changes Have Affected Past Climate"	Assessment Outcome 3 (Assessment items 4, 5)
Reading—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age"	Assessment Outcomes 4, 5 (Assessment item 6)
Reading—"How Fast Can the Climate Change?"	Assessment Outcome 6 (Assessment item 9)
Activity 4—"What is Happening Now and What's Projected for the Future?"	Assessment Outcome 7
Reading—"Sorting Out Natural and Human-induced Climate Change"	Assessment Outcome 8 (Assessment item 7)
Address the Challenge	Students' abilities to synthesize what they have learned from their study of Earth's climate history and teach it to others through a museum exhibit
Process	
Share	Students' understandings of the key concepts covered in this chapter
Discuss	Students' ideas about how their thoughts about climate have changed since the beginning of this unit, and their abilities to synthesize what they have learned, relating phrases and terms used in this chapter to the concept of climate change
Assessment	Students' understandings of the range of concepts presented throughout the chapter; these questions can be used in class, for homework, or as a quiz at the end of the chapter

The scope and sequence section in each chapter is a powerful tool for lesson planning and scheduling.

Many teachers tell us they wouldn't consider teaching the course without it!



Scope and Sequence

The following is provided to help with your lesson planning. Adjust it according to the needs and interests of your classroom, and whether you assign readings as homework or complete them in class.

WEEK			DAY		PREVIEW
1	Consider		1	Introduce chapter and discuss *Brainstorming* questions	Students brainstorm what they know about Earth's history—in particular, the Cretaceous Period in which dinosaurs lived and the Pleistocene Ice Age. They think about how climate could have been so much colder during the Pleistocene and about ways that studying climate change in Earth's history could help humans better understand climate change that is happening now.
1	Consider		2	Read/discuss *What's the Story*—"Journey to a Different Time" Introduce *Challenge*	Students read a story about a very warm point in Earth's history when no polar ice caps existed and a very cold point in Earth's history when ice covered much of North America. They think about what might have caused Earth's climate to change so dramatically in the past and what might cause the climate to change now and in the future.
1	Investigate	Gather Knowledge	3	*Activity 1*—"Looking for Clues to the Past"	Students practice looking for evidence of events that have happened in the past by looking for clues around the classroom.
1	Investigate	Gather Knowledge	4	*Reading*— "Evidence of Earth's Past"	Students read about climate proxies—tools used by scientists to investigate Earth's climate history. They summarize what they have learned and think about the importance of collecting climate proxy data from different locations around Earth.
1	Investigate	Gather Knowledge	5	*Activity 2*—"Using Climate Proxies"	Students use simulated proxy data from sediment cores to determine past ocean temperatures.
2	Investigate	Gather Knowledge	6	*Activity 3*—"Investigating How Orbital Changes Have Affected Past Climate"	Students use a model Earth and Sun to demonstrate the Milankovitch cycles and think about how these orbital cycles affect the intensity of Earth's seasons and in turn the advance and retreat of ice sheets during the Pleistocene.
2	Investigate	Gather Knowledge	7	*Reading*—"The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Cretaceous"	Students read about how plate tectonic movements occurring over very long periods of time have led to warm and cool periods in Earth's history. They think about how climate change in the past is relevant to Earth's future.
2	Investigate	Gather Knowledge	8	*Reading*—"How Fast Can the Climate Change?"	Students read about abrupt climate change events that have occurred in Earth's history and the potential causes of these events.
2	Investigate	Gather Knowledge	9	*Activity 4*—"What's Happening Now and What's Projected for the Future," Part A	Students study the predictions of global climate models and relate them to observed changes in global temperature, sea-level rise, ice measurements, ocean acidification and precipitation.
2	Investigate	Gather Knowledge	10	*Activity 4*—"What's Happening Now and What's Projected for the Future," Part B	
3	Investigate	Address the Challenge	11	*Reading*—"Sorting Out Natural and Human-Induced Climate Change	Students read about how scientists use their understanding of Earth's climate history to assess whether climate change happening now is due to natural processes or human activities. They summarize evidence that human activities are contributing to the current warming trend.
3	Investigate	Address the Challenge	12	*Address the Challenge:* Create Museum Exhibit	Students prepare museum exhibits that explain the key concepts they studied in this chapter.
3	Process		13	*Share* exhibits	Students share their museum exhibits and review the major concepts covered in this chapter.
3	Process		14	*Discuss* concept mapping	Students discuss how their ideas about climate have changed since the beginning of the unit and review the complex factors that can bring about climate change by creating a concept map that relates the various terms and phrases used in this chapter.
3	Review		15	Review	
3	Assessment		16	Summative Assessment	

The notes on materials and preparation provide detailed instructions to prepare for the lessons.

These include notes on safety, dividing students into groups, and handling of materials.

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Materials and Preparation

Note: All reproducible pages (Student Sheets, Literacy Supplements, and Resource Supplements) and many images from the Student Book can be found in the Teacher Resources as pdfs or slide presentations.

You may choose to use the following optional literacy supplements:

- Literacy Supplement L6.1: *Anticipation Guide* for "Journey to Another Time"
- Literacy Supplement L6.2: *Three-Level Reading Guide* for "Evidence of Earth's Past"
- Literacy Supplement L6.3: *Three-Level Reading Guide* for "The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age"
- Literacy Supplement L6.4: *Science Fact Triangle* for "How Fast Can the Climate Change?"
- Literacy Supplement L6.5: *Science Fact Triangle* for "Sorting Out Natural and Human-Induced Climate Change"

You may want to place a poster with a geologic timeline on the wall to refer to during this chapter.

Prior to Activity 2—"Using Climate Proxies"

1. Gather the materials listed below.

FOR THE TEACHER
- gravel, "foram" sheets, and 16 plastic "sediment core" tubes (see Step 2 below)

FOR EACH TEAM OF STUDENTS
- 1 "sediment core" (containing gravel and "forams") (see Step 2 below)
- 1 tray (for sorting contents of "sediment core")
- 1 calculator*

FOR EACH STUDENT
- ruler (optional)
- graph paper*

*not included in LAB-AIDS equipment package

Foram Counts for Activity 2

AGE (YBP = years before present)	FORAM COLOR	FORAM TYPE: RIGHT COILING	LEFT COILING	OTHER
0 ybp (today)	dark blue	42	8	25
30,000 ybp	yellow	10	40	25
60,000 ybp	gray	16	34	25
90,000 ybp	green	41	9	25
120,000 ybp	orange	44	6	25
150,000 ybp	light blue	11	39	25
180,000 ybp	brown	13	37	25
210,000 ybp	pink	23	27	25

2. Check the number of "forams" in each plastic "sediment core" tube (see Foram Counts table). There should be one striped set and one solid set for each age. Sort them if they are mixed. Punch out the forams, if using for the first time, and add with about 200 cm³ of gravel to the tubes.
3. Create a class data table similar to the Foram Counts table. Post it so teams can record their data.

Prior to Activity 3—"Investigating How Orbital Changes Have Affected Past Climate"

1. Gather the materials listed below.

FOR EACH TEAM OF STUDENTS
- 1 plastic "planet" with wooden axis (see Step 2 below)
- access to a light source*
- marker

*not included in LAB-AIDS equipment package

2. If needed, assemble the "plastic planets" by connecting the two halves and inserting a wooden dowel for the axis.

Prior to Activity 4—"What is Happening Now and What's Projected for the Future"

1. Gather the materials listed below.

PART A—FOR EACH STUDENT
- ruler (optional)
- graph paper*

PART B—FOR THE CLASS
- 2 sets Expert Group 1 Data Cards (Figs. 6.20, 6.21 in student book)
- 2 sets Expert Group 2 Data Cards (Figs 6.22, 6.23 in student book)
- 2 Expert Group 3 Data Cards (Fig. 6.24 in student book)
- 2 sets Expert Group 4 Data Cards (Figs. 6.25, 6.26 in student book)
- means of projecting Expert Group Data Cards* (see step 2 below)

*not included in LAB-AIDS equipment package

2. Projectable Expert Group Data card images are in the Chapter 6 slide presentation in Teacher Resources.

Prior to Address the Challenge

1. Gather materials for students to use to create visuals for their museum exhibits.

Prior to Process

1. Optional Resource Supplement R6.1: *Climate Change Concept Map* is available in Teacher Resources or the Chapter 6 slide presentation.
2. You may want to invite another class or community members to view students' museum exhibits.

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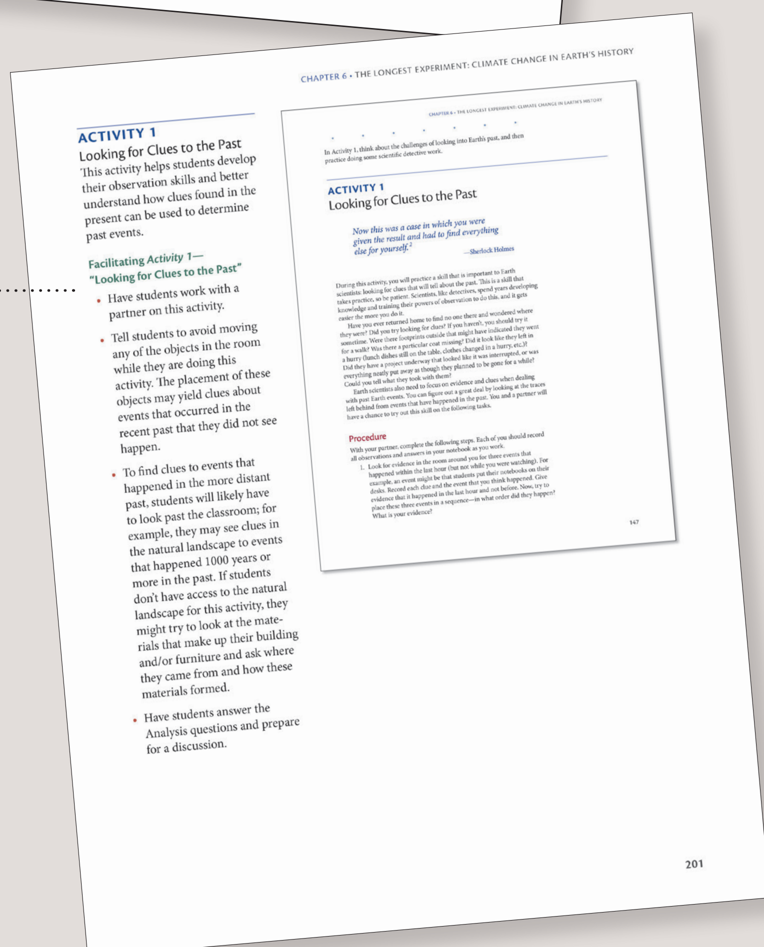
Detailed instructions for teaching the activities are provided in wrap-around format.



CHAPTER 6 • THE LONGEST EXPERIMENT: CLIMATE CHANGE IN EARTH'S HISTORY

ACTIVITY 1
Looking for Clues to the Past

This activity helps students develop their observation skills and better understand how clues found in the present can be used to determine past events.

Facilitating Activity 1—"Looking for Clues to the Past"

- Have students work with a partner on this activity.
- Tell students to avoid moving any of the objects in the room while they are doing this activity. The placement of these objects may yield clues about events that occurred in the recent past that they did not see happen.
- To find clues to events that happened in the more distant past, students will likely have to look past the classroom; for example, they may see clues in the natural landscape to events that happened 1000 years or more in the past. If students don't have access to the natural landscape for this activity, they might try to look at the materials that make up their building and/or furniture and ask where they came from and how these materials formed.
- Have students answer the Analysis questions and prepare for a discussion.

CHAPTER 6 • THE LONGEST EXPERIMENT: CLIMATE CHANGE IN EARTH'S HISTORY

In Activity 1, think about the challenges of looking into Earth's past, and then practice doing some scientific detective work.

ACTIVITY 1
Looking for Clues to the Past

Now this was a case in which you were given the result and had to find everything else for yourself.[2]
—Sherlock Holmes

During this activity, you will practice a skill that is important to Earth scientists: looking for clues that will tell about the past. This is a skill that takes practice, so be patient. Scientists, like detectives, spend years developing knowledge and training their powers of observation to do this, and it gets easier the more you do it.

Have you ever returned home to find no one there and wondered where they were? Did you try looking for clues? If you haven't, you should try it sometime. Were there footprints outside that might have indicated they went for a walk? Was there a particular coat missing? Did it look like they left in a hurry (lunch dishes still on the table, clothes changed in a hurry, etc.)? Did they have a project underway that looked like it was interrupted, or was everything neatly put away as though they planned to be gone for a while? Could you tell what they took with them?

Earth scientists also need to focus on evidence and clues when dealing with past Earth events. You can figure out a great deal by looking at the traces left behind from events that have happened in the past. You and a partner will have a chance to try out this skill on the following tasks.

Procedure

With your partner, complete the following steps. Each of you should record all observations and answers in your notebook as you work.

1. Look for evidence in the room around you for three events that happened within the last hour (but not while you were watching). For example, an event might be that students put their notebooks on their desks. Record each clue and the event that you think happened. Give evidence that it happened in the last hour and not before. Now, try to place these three events in a sequence—in what order did they happen? What is your evidence?

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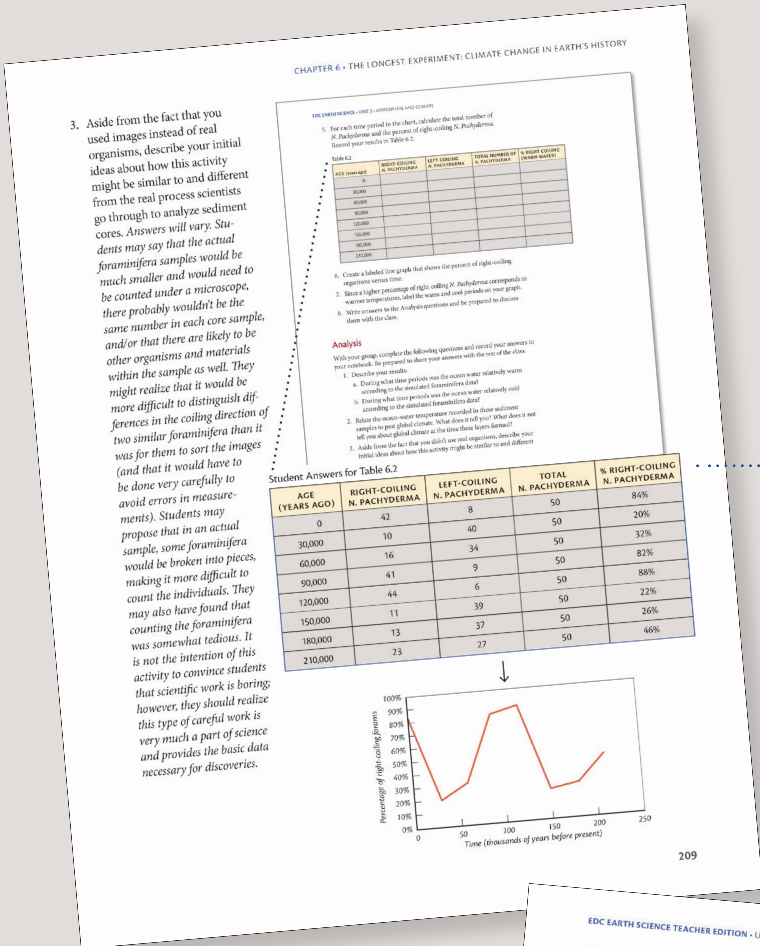
CHAPTER 6 • THE LONGEST EXPERIMENT: CLIMATE CHANGE IN EARTH'S HISTORY

3. Aside from the fact that you used images instead of real organisms, describe your initial ideas about how this activity might be similar to and different from the real process scientists go through to analyze sediment cores. *Answers will vary. Students may say that the actual foraminifera samples would be much smaller and would need to be counted under a microscope, there probably wouldn't be the same number in each core sample, and/or that there are likely to be other organisms and materials within the sample as well. They might realize that it would be more difficult to distinguish differences in the coiling direction of two similar foraminifera than it was for them to sort the images (and that it would have to be done very carefully to avoid errors in measurements). Students may propose that in an actual sample, some foraminifera would be broken into pieces, making it more difficult to count the individuals. They may also have found that counting the foraminifera was somewhat tedious. It is not the intention of this activity to convince students that scientific work is boring; however, they should realize this type of careful work is very much a part of science and provides the basic data necessary for discoveries.*

Student Answers for Table 6.2

AGE (YEARS AGO)	RIGHT-COILING N. PACHYDERMA	LEFT-COILING N. PACHYDERMA	TOTAL N. PACHYDERMA	% RIGHT-COILING N. PACHYDERMA
0	42	8	50	84%
30,000	10	40	50	20%
60,000	16	34	50	32%
90,000	41	9	50	82%
120,000	44	6	50	88%
150,000	11	39	50	22%
180,000	13	37	50	26%
210,000	23	27	50	46%

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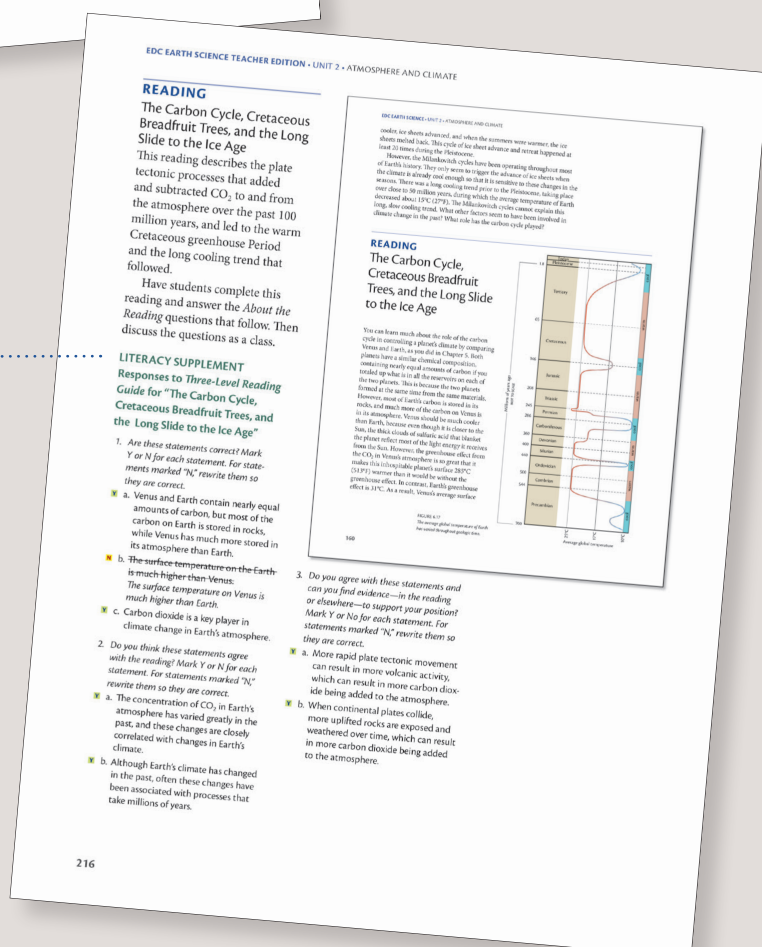
Sample data for laboratory activities are provided for the teacher.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READING

The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age

This reading describes the plate tectonic processes that added and subtracted CO_2 to and from the atmosphere over the past 100 million years, and led to the warm Cretaceous greenhouse Period and the long cooling trend that followed.

Have students complete this reading and answer the *About the Reading* questions that follow. Then discuss the questions as a class.

LITERACY SUPPLEMENT

Responses to *Three-Level Reading Guide* for "The Carbon Cycle, Cretaceous Breadfruit Trees, and the Long Slide to the Ice Age"

1. *Are these statements correct? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*
   - Y a. Venus and Earth contain nearly equal amounts of carbon, but most of the carbon on Earth is stored in rocks, while Venus has much more stored in its atmosphere than Earth.
   - N b. ~~The surface temperature on the Earth is much higher than Venus.~~ *The surface temperature on Venus is much higher than Earth.*
   - Y c. Carbon dioxide is a key player in climate change in Earth's atmosphere.
2. *Do you think these statements agree with the reading? Mark Y or N for each statement. For statements marked "N," rewrite them so they are correct.*
   - Y a. The concentration of CO_2 in Earth's atmosphere has varied greatly in the past, and these changes are closely correlated with changes in Earth's climate.
   - Y b. Although Earth's climate has changed in the past, often these changes have been associated with processes that take millions of years.
3. *Do you agree with these statements and can you find evidence—in the reading or elsewhere—to support your position? Mark Y or No for each statement. For statements marked "N," rewrite them so they are correct.*
   - Y a. More rapid plate tectonic movement can result in more volcanic activity, which can result in more carbon dioxide being added to the atmosphere.
   - Y b. When continental plates collide, more uplifted rocks are exposed and weathered over time, which can result in more carbon dioxide being added to the atmosphere.

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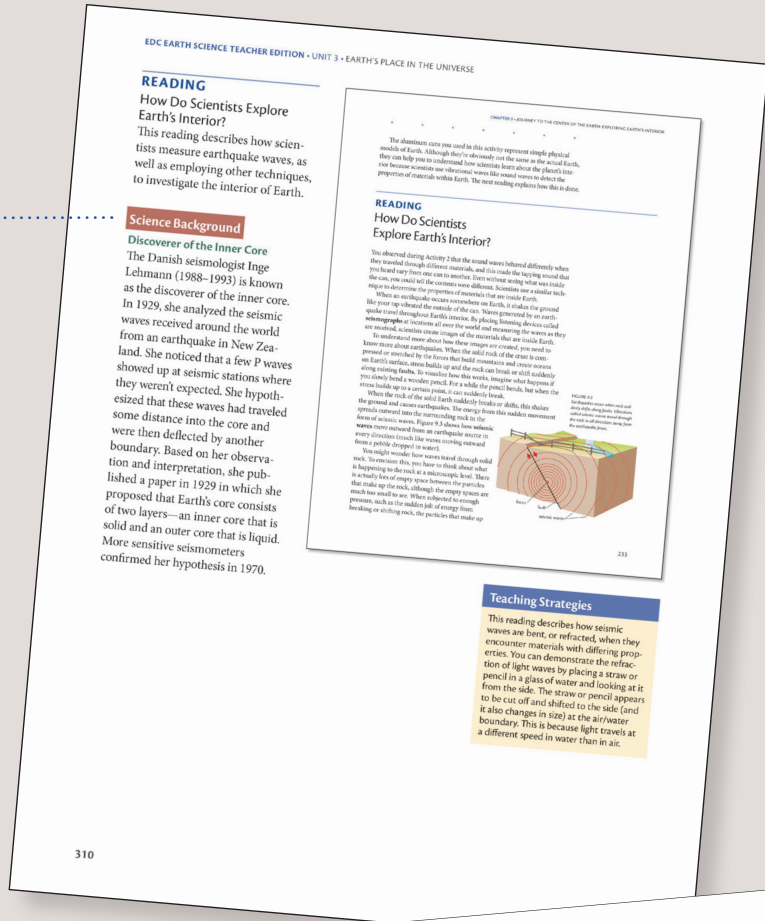
Answers to analysis questions and literacy supplements are provided for the teacher.

Science Background and Teaching Strategies sections help teachers introduce and review key concepts.



EDC EARTH SCIENCE TEACHER EDITION • UNIT 3 • EARTH'S PLACE IN THE UNIVERSE

READING
How Do Scientists Explore Earth's Interior?
This reading describes how scientists measure earthquake waves, as well as employing other techniques, to investigate the interior of Earth.

Science Background
Discoverer of the Inner Core
The Danish seismologist Inge Lehmann (1988–1993) is known as the discoverer of the inner core. In 1929, she analyzed the seismic waves received around the world from an earthquake in New Zealand. She noticed that a few P waves showed up at seismic stations where they weren't expected. She hypothesized that these waves had traveled some distance into the core and were then deflected by another boundary. Based on her observation and interpretation, she published a paper in 1929 in which she proposed that Earth's core consists of two layers—an inner core that is solid and an outer core that is liquid. More sensitive seismometers confirmed her hypothesis in 1970.

READING
How Do Scientists Explore Earth's Interior?

Teaching Strategies
This reading describes how seismic waves are bent, or refracted, when they encounter materials with differing properties. You can demonstrate the refraction of light waves by placing a straw or pencil in a glass of water and looking at it from the side. The straw or pencil appears to be cut off and shifted to the side (and it also changes in size) at the air/water boundary. This is because light travels at a different speed in water than in air.

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Many chapters contain a relevant section on careers in the earth sciences.

EDC EARTH SCIENCE TEACHER EDITION • UNIT 4 • PLATE TECTONICS

Science Background
Earthquake Precursors
Scientists expect that there will be some precursors to a large earthquake in California. For example, there is likely to be a period of increased seismicity over several years with smaller earthquakes occurring. They expect that there may be changes in the shape of the ground surface that can be measured with GPS technology. To better understand these precursors, research is currently underway in the Parkfield region in central California, where moderate-size earthquakes occur fairly frequently.

Listening for Understanding
As students answer the Discuss questions, listen for their understanding of the physical changes that occur along the San Andreas Fault zone that generate earthquakes. When they discuss the physical and computer models, make sure they are thinking about how these models do and do not resemble real Earth.

Career: Earthquake Engineer

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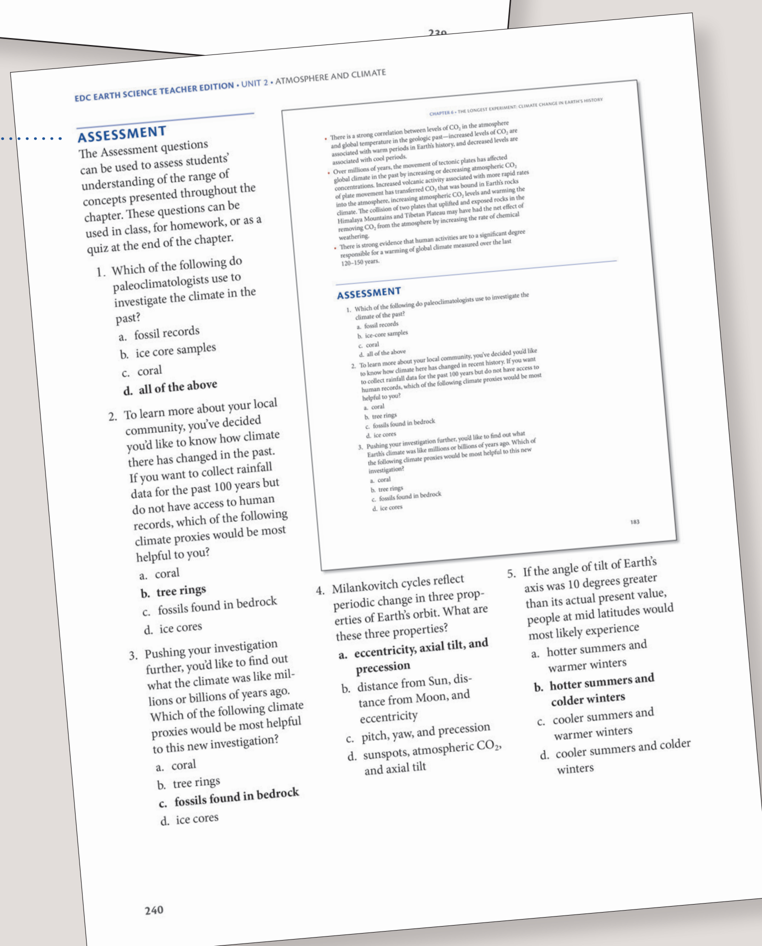
Each chapter concludes with a review of the major concepts covered.

This helps students build a "big picture" understanding of earth science.

Detailed answers to end-of-chapter assessment questions and suggestions for how to use them are provided for the teacher.


EDC EARTH SCIENCE TEACHER EDITION • UNIT 2 • ATMOSPHERE AND CLIMATE

ASSESSMENT

The Assessment questions can be used to assess students' understanding of the range of concepts presented throughout the chapter. These questions can be used in class, for homework, or as a quiz at the end of the chapter.

1. Which of the following do paleoclimatologists use to investigate the climate in the past?
   a. fossil records
   b. ice core samples
   c. coral
   d. all of the above
2. To learn more about your local community, you've decided you'd like to know how climate there has changed in the past. If you want to collect rainfall data for the past 100 years but do not have access to human records, which of the following climate proxies would be most helpful to you?
   a. coral
   b. tree rings
   c. fossils found in bedrock
   d. ice cores
3. Pushing your investigation further, you'd like to find out what the climate was like millions or billions of years ago. Which of the following climate proxies would be most helpful to this new investigation?
   a. coral
   b. tree rings
   c. fossils found in bedrock
   d. ice cores
4. Milankovitch cycles reflect periodic change in three properties of Earth's orbit. What are these three properties?
   a. eccentricity, axial tilt, and precession
   b. distance from Sun, distance from Moon, and eccentricity
   c. pitch, yaw, and precession
   d. sunspots, atmospheric CO_2, and axial tilt
5. If the angle of tilt of Earth's axis was 10 degrees greater than its actual present value, people at mid latitudes would most likely experience
   a. hotter summers and warmer winters
   b. hotter summers and colder winters
   c. cooler summers and warmer winters
   d. cooler summers and colder winters

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EDC Earth Science Semester 1

EDC Earth Science Semester 2

You will find more information regarding the content of this course at the beginning of each chapter in the teacher edition, along with information about the crosscutting concepts and scientific practices embedded in the chapter activities and readings.

NGSS ALIGNMENT

The following table shows the correlation between the concepts addressed in *EDC Earth Science* and *the Next Generation Science Standards* (NGSS, 2013).

Correlation of *EDC Earth Science* with the *Next Generation Science Standards* for High School (9–12)

NGSS HS EARTH AND SPACE SCIENCE STANDARD	Where found in *EDC Earth Science*	
	Unit(s) and Title	Chapter(s) and Pages
EARTH'S PLACE IN THE UNIVERSE (ESS1)		
HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.	3: Earth's Place in the Universe	8: 200-203, 212-215
HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	3: Earth's Place in the Universe	8: 200-206
HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.	3: Earth's Place in the Universe	8: 200-201
HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	3: Earth's Place in the Universe	8: 208-209
HS-ESS1-5: Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	4: Plate Tectonics 5: The Rock Cycle	10: 256-260 12: 342-347 14: 399-401, 415-426
HS-ESS1-6: Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of.	3: Earth's Place in the Universe 5: The Rock Cycle	9: 195-199, 203-206 14: 415-426
EARTH'S SYSTEMS (ESS2)		
HS-ESS2-1: Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	3: Earth's Place in the Universe 4: Plate Tectonics 5: The Rock Cycle	9: 241-244 10: 250-279 11: 289-322 12: 336-345, 350-352 13: 363-389 14: 415-426
HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate	3: 66-70, 72-76 4: 102-106 5: 115-135 6: 155-164
HS-ESS2-3: Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	3: Earth's Place in the Universe 4: Plate Tectonics	9: 241-244 11: 317-319 12: 342-352
HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate	3: 66-76 4: 94-98 5: 115-123 6: 165-178

Correlation of *EDC Earth Science* with the *Next Generation Science Standards* for High School (9–12)

NGSS HS EARTH AND SPACE SCIENCE STANDARD	Where found in *EDC Earth Science*	
	Unit(s) and Title	Chapter(s) and Pages
HS-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate	2:24-35 3: 58-76 4: 99-103 5: 116-124, 133-135 6: 165-175
HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere.	2: Atmosphere and Climate	5: 124-135 6: 160-163
HS-ESS2-7: Construct an argument based on evidence about the coevolution of Earth's systems and life on Earth. (Changes in the atmosphere from plants and other organisms along with feedback mechanisms.)	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate 5: The Rock Cycle 6: Earth Resources	2: 36-40 5: 127-135 6: 165-178 13: 387-389 14: 425-426 15: 447-453 16: 479-485
HS-ESS2-8: Evaluate data and communicate information to explain how the movement and interactions of air masses result in changes in weather conditions.	2: Atmosphere and Climate	4: 97-98, 102-103, 104-106
EARTH AND HUMAN ACTIVITY (ESS3)		
HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	1: Hydrosphere: Water in Earth's Systems 4: Plate Tectonics 5: The Rock Cycle 6: Earth Resources	2: 18-20, 38-40 10: 250-253, 283-284 11: 290-292, 321-322 13: 358-361, 387-389 15: 432-435, 444-456 16: 461-468, 479-485
HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost benefit ratios.	6: Earth Resources	16: 482-484
HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate 6: Earth Resources	2:18-23 5: 127-132 6: 165-178 16: 463-467
HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	1: Hydrosphere: Water in Earth's Systems 5: The Rock Cycle 6: Earth Resources	2: 38-40 13: 387-389 16: 479-481
HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	2: Atmosphere and Climate	6: 165-178
HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	2: Atmosphere and Climate	5: 127-135 6: 165-175

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