Lesson 2.7 from

OCEAN SCIENCES SEQUENCE FOR GRADES 6–8

Teacher's Guide

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

Great Explorations in Math and Science (GEMS®)

Lawrence Hall of Science
University of California, Berkeley

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

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Lawrence Hall of Science
University of California, Berkeley, CA 94720-5200.
Director: Elizabeth K. Stage

GEMS Director: Jacqueline Barber
MARE Director: Craig Strang
Project Directors: Catherine Halversen (Co-Director, MARE), Janice McDonnell (Institute of Marine and Coastal Sciences, Rutgers University), Craig Strang, and Jacqueline Barber
Curriculum Development Team: Catherine Halversen, Kevin Beals, Jonathan Curley, Emily Weiss, Carolyn Willard; Emily Arnold, Lynn Barakos, and Sarah Pedemonte
Assessment Development: Seth Corrigan, Lauren Brodsky; and Lynn Barakos
Science Advisors and Reviewers: Dr. Bob Chant, Dr. Jim Miller, Dr. John Wilkin, Dr. Elizabeth Sikes, Dr. Oscar Schofield, Dr. Josh Kohut, Dr. Carrie Ferraro, Kristin Hunter-Thomson, and Janice McDonnell (Institute of Marine and Coastal Sciences, Rutgers University), Dr. Drew Talley (University of San Diego), Dr. Adina Paytan (University of California, Santa Cruz), Dr. Robert Rhew and Dr. John Chiang (University of California, Berkeley), Dr. Michael Mann (University of Pennsylvania), Paulo Maurin (NOAA Coral Reef Conservation Program), Dr. John Manderson (National Marine Fisheries Service), Eric Simms and Daniel Richter (Scripps Institution of Oceanography), Dr. Fritz Stahr (University of Washington), and Dr. Jen Skene (University of California, Berkeley)
Ocean Science Educator Advisors and Reviewers: Terri Kirby Hathaway (North Carolina Sea Grant), Dr. Diana Payne (University of Connecticut, Sea Grant), and Sarah Ferner (San Francisco National Estuarine Research Reserve, Romberg Tiburon Center for Environmental Studies, San Francisco State University)
Technology Development: Igor Heifetz, Brian Yan, Sage Lichtenwalner, Carrie Ferraro, and Janice McDonnell (Institute of Marine and Coastal Sciences, Rutgers University), Steven Dunphy (Lawrence Hall of Science)
Field Trial Management and Research: Phaela Peck and Lynn Tran
Editor: Barbara Clinton
Production Manager: Steven Dunphy
Illustrations: Lisa Haderlie Baker, Barbara Clinton, Sarah Kessler, and Carolyn Willard
NOAA Program Officer: Sarah Schoedinger

This curriculum and DVD were prepared by the University of California, Berkeley, under award NA09SEC4690010 from the National Oceanic and Atmospheric Administration (NOAA), U. S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration (NOAA) or the U. S. Department of Commerce.

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
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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)
Published by Carolina Biological Supply Company. 2700 York Road, Burlington, NC 27215.
Call toll free: 1-800-334-5551.
www.carolinacurriculum.com/GEMS/
1 2 3 4 5 6 7 8 9 10   14 13 12 11 10

UNIT OVERVIEW

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.

SESSION SUMMARIES

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.

Investigating Combustion and the Carbon Cycle

In the previous session, students learned about how carbon flows into the reservoirs of fossil fuels and limestone. In this session, students investigate how carbon can move out of those reservoirs. Groups examine a set of Flow Cards and identify two flows that take carbon out of fossil fuels and two that take carbon out of limestone. The class focuses on one of these flows, Human Industry: Combustion of Fossil Fuels. The teacher burns a paraffin candle to demonstrate how the carbon in fossil fuel is converted to CO_2 in the atmosphere during combustion. Next, the class explores two models of the carbon cycle with a continuing focus on combustion of fossil fuels: first a computer model, the Interactive Carbon Cycle Diagram, and then a model using dice and colored paper clips that allows students to follow carbon as it flows through many reservoirs. Students run that model once with only natural flows out from fossil fuel reservoirs and once with human combustion of fossil fuels. A graph shows that human combustion of fossil fuels has increased dramatically in recent decades. Student learning is focused on the following key concepts:

- Carbon moves between reservoirs, but the total amount of carbon on Earth doesn't change.
- Human industry moves carbon out of fossil fuel and limestone reservoirs and into the atmosphere.

Students also learn:

- Fossil fuels and many other things produce CO_2 when they combust.
- Natural flows move small amounts of carbon out of the reservoirs of fossil fuels and limestone.
- One carbon atom may move through many different reservoirs.
- Every scientific model has ways in which it is accurate and ways in which it is inaccurate.

Investigating Combustion and the Carbon Cycle	Estimated Time
Tracing Carbon Flow out of Fossil Fuel and Limestone Reservoirs	15 minutes
Demonstrating Combustion	5 minutes
Exploring the Interactive Carbon Cycle Diagram	5 minutes
Exploring the Paper Clip Carbon Cycle Model	20 minutes
Total	**45 minutes**

UNIT GOALS

SCIENCE CONTENT
- Carbon Cycle

PRACTICES OF SCIENCE
- Making explanations from evidence
- Interpreting and creating diagrams

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.B.10. Humans obtain energy from the ocean via wind, wave, oil, and natural gas.

Climate Literacy Principle 6.A. Human activities are impacting the climate system.

WHAT YOU NEED

For the class:
- ❏ projection system*
- ❏ computer with Internet connection* or resource disc
- ❏ 5 slides for Session 2.7
- ❏ simulation, *Interactive Carbon Cycle Diagram*
- ❏ 1 paraffin candle
- ❏ matches*
- ❏ 1 pie tin
- ❏ paper towel*
- ❏ Copymaster Packet

For each group of students:
- ❏ 19 Flow cards from Carbon Cycle Cards set (set/30)
- ❏ 1 envelope
- ❏ 1 six-sided die
- ❏ 50 colored paper clips (10 of each color)
- ❏ 5 self-sealing plastic bags
- ❏ 1 Paper Clip Carbon Cycle Model #1 sheet
- ❏ 1 Paper Clip Carbon Cycle Model #2 sheet

For each student:
- ❏ Investigation Notebook: pages 3–4, 17; optional page 20 (DWR)

*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, follow the links (eBook), or use the resource disc (print version).
2. **Preview Interactive Carbon Cycle Diagram.** Explore this computer model to become familiar with the various settings and pop-up windows.
3. **Prepare Flow cards.** Separate the Carbon Cycle Card sets by colored borders (16 green, 11 blue, and 3 black), and for each group of students, place the 19 Flow cards (green borders and black borders) into an envelope.
4. **Prepare self-sealing bags with colored paper clips.** For each group of students, place 10 paper clips of each color into a small plastic bag, so each color is in its own bag.
5. **Prepare student sheets.** Copy the following pages from the Copymaster Packet:
   - _ Paper Clip Carbon Cycle Model #1 (one for each group)
   - _ Paper Clip Carbon Cycle Model #2 (one for each group)

LANGUAGE OF SCIENCE

VOCABULARY
absorb
atmosphere
atom
carbon
carbon cycle
carbon dioxide/CO_2
carbon flow
carbon reservoir
combustion
decompose/decomposition
evidence
fossil fuels
matter
model
molecule
organism
photosynthesis
respiration

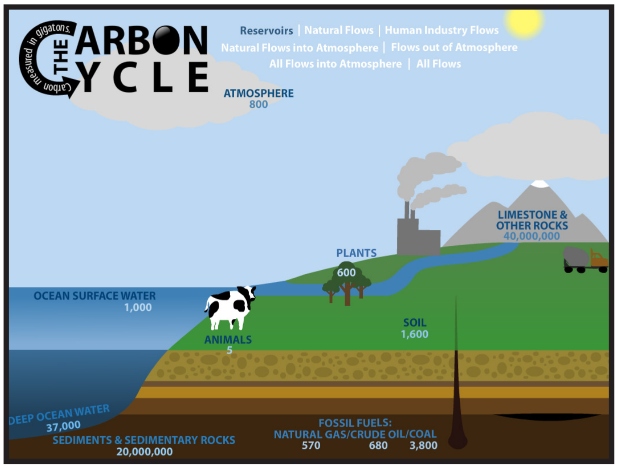
LANGUAGE OF ARGUMENTATION
What do you think?
Why do you think that?
What is your evidence?
Do you agree? Why?
Do you disagree? Why?
How sure are we?
How could we be more sure?

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

Tracing Carbon Flow out of Fossil Fuel and Limestone Reservoirs

1. **Collect homework.** Collect students' Carbon Cycle Diagrams and tell them that they will get them back to use during their final writing for the unit.

2. **Project and introduce the Interactive Carbon Cycle Diagram.** Project the "Reservoirs" view of the interactive diagram. Say, **"This computer model is similar to your Carbon Cycle Diagrams. You can click on parts of the carbon cycle to get more information."** Tell students that they will use the model in this and coming sessions.



3. **Explore fossil fuel and limestone reservoirs on the interactive diagram.** Remind students that they learned how carbon gets into reservoirs of coal, crude oil, and limestone. Click on the fossil fuels reservoir and have a student read the information aloud. Then do the same for the limestone reservoir.

4. **Ask how carbon might flow out of these reservoirs.** Say, **"Last session, you learned how carbon flows into reservoirs of coal, crude oil, and limestone. How do you think carbon might come out of these reservoirs?"** Tell students that they will be investigating this today.

5. **Introduce Flow Cards and the search for carbon flowing out of four reservoirs.** Hold up a set of 19 Flow Cards. Tell students that their group's task will be to examine these 19 cards and find the four cards that describe flows out of fossil fuel or limestone reservoirs. Tell students they should also notice the other flow cards—some describe flows students have learned about and some describe other flows.

6. **Groups find flow cards showing flows out of fossil fuel and limestone reservoirs.** Pass each group of four a set of Flow Cards and have them begin looking through to identify the two cards that describe flows out of fossil fuel reservoirs [Natural Leakage and Breakdown of Fossil Fuels; Human Industry: Combustion of Fossil Fuels.] and the two that describe flows out of limestone. [Volcanic Eruptions; Human Industry: Making Cement.]

TEACHER CONSIDERATIONS

DAILY WRITTEN REFLECTION

Why do some dead organisms decompose and others turn into fossil fuel or limestone? What is the difference? This prompt, on page 20 of the Investigation Notebook, asks students to refer back to what they learned in the previous session. They should explain that the carbon in dead organisms can only become fossil fuels or limestone if it is buried where there are no decomposer organisms and then subjected to high pressure and heat over millions of years.

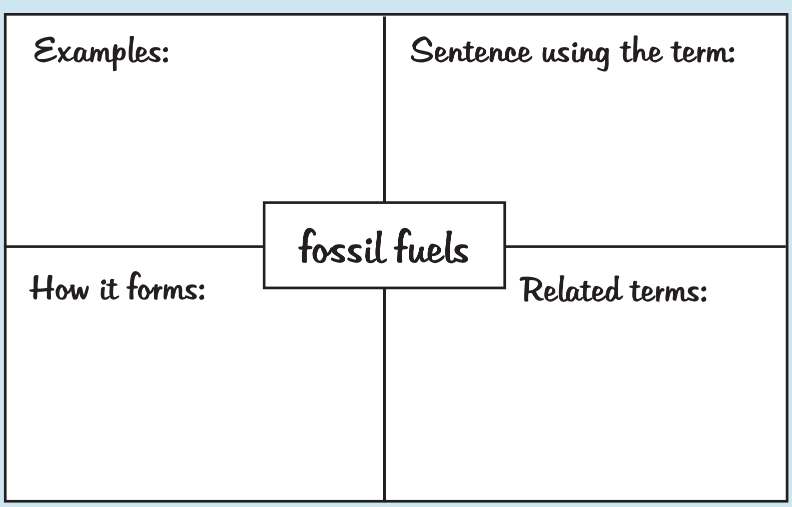
INSTRUCTIONAL RATIONALE

Reasons for Sorting through Flow Cards. The process of sorting through the Flow cards in order to find those that show carbon leaving fossil fuel and limestone reservoirs is beneficial in a few ways. It is a chance for students to review what they learned about the carbon cycle as they examine each card. It also allows for an element of discovery as each group finds the cards that reveal how carbon moves out of these reservoirs.

Students Will Use Gigaton information Next Session. Students may notice that each Flow card includes a number for gigatons. This information will be a focus of Session 2.8. For now, you can tell students that these numbers will help them compare which flows are larger and which are smaller.

ENGLISH LANGUAGE LEARNERS

Vocabulary Scaffold. Complex science vocabulary is often a challenge for ELLs. You can help ELLs succeed in this and coming sessions by reviewing the term *fossil fuels* near the beginning of the session. Have students help you complete a word map on chart paper, as shown below, and then post the word map on the wall.



LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
atom
carbon
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carbon dioxide/CO_2
carbon flow
carbon reservoir
combustion
decompose/decomposition
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fossil fuels
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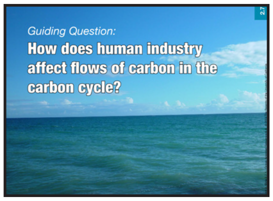
LANGUAGE OF ARGUMENTATION

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. **Each group member reads aloud one of the four cards to group.** Once most groups have found the correct four cards, get the class's attention. Have groups pass one of these four cards to each group member, and set aside the remaining 15 Flow Cards. Have group members take turns reading the back of the one Flow Card they're holding aloud to the rest of the group. Then collect all the Flow Cards.

8. **Project a new guiding question.** Say, **"Most of the carbon that flows out of these reservoirs is because of human industry."** Project the new guiding question and have a student read it aloud.



Demonstrating Combustion

1. **Introduce a candle as a fossil fuel.** Tell students that the class will now focus on the combustion (burning) of fossil fuels since this is the biggest flow of carbon out of fossil fuel reservoirs. Hold up the candle and explain that it is made of paraffin wax, which is made from crude oil. When this wax burns, it keeps the flame on the wick of the candle lit.

2. **Light the candle and collect soot.** Set the candle in a safe location where students can see it. Light the candle. After a moment, hold the aluminum pie pan directly in the candle flame for a few seconds. When you remove it from the flame, show students the black soot on the pie pan. Rub some off with your finger or a paper towel, then hold your blackened finger or paper towel up for the class to see.

3. **Turn and Talk: discuss where carbon goes.** Ask **"Where is the carbon from the wax and wick going?"** and have students discuss this with a partner. After a minute or so, have a few students share their ideas. Ask, **"What do you think?" "Why?" "What is your evidence?"** Then explain that during combustion, the fuel (in this case, mostly wax) changes into gases—including CO_2—and heat is released. The black soot and smoke are mostly leftover carbon solids that did not change into gases during combustion. Blow out the candle.

TEACHER CONSIDERATIONS

INSTRUCTIONAL SUGGESTIONS

Students Do Candle Investigation. If you feel comfortable with having students do the candle investigation in pairs, rather than as a teacher demo, you will need to collect a few additional materials including a candle, a match, and an aluminum pie plate for each pair. Pose the question of where the carbon in the candle goes during combustion, and challenge students to gather information as their candle burns. You will need to set very strict safety guidelines if you choose this option, for example, making sure no student touches a candle or flame during the combustion, that all other materials are cleared off desks, that students hold the pie pans at a minimum height of at least one foot above the candle, and that everyone stays seated and still once candles are burning.

SCIENCE NOTES

About Combustion. When fossil fuels combust, hydrogen molecules in the fossil fuels react with O_2 molecules in the air. One product of this reaction is CO_2, which moves into the air. The burning of fossil fuels releases carbon into Earth's atmosphere immediately, and that rapidly increases the amount of carbon in Earth's atmosphere since it builds up in the atmosphere faster than it can flow into other reservoirs.

PROVIDING MORE EXPERIENCE

Extend: Trace Back the Carbon for Combustion. Lead a brief class brainstorm in which students generate a list of different substances that people burn (wood, paper, lighter fluid, charcoal, natural gas in stoves). Tell students that engines must burn fuel to run and add to the list (gasoline, diesel fuel). Explain that all these things have carbon in them. Choose one of these substances as a class, and trace back two or three steps to where its carbon came from. For example, wood from a tree which got its carbon from CO_2 in the air that it took in during photosynthesis. Have each pair of students choose another substance and trace it back in a similar way. You could have them record this in writing or by making a simple diagram.

LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
atom
carbon
carbon cycle
carbon dioxide/CO_2
carbon flow
carbon reservoir
combustion
decompose/decomposition
evidence
fossil fuels
matter
model
molecule
organism
photosynthesis
respiration

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?

Exploring the Interactive Carbon Cycle Diagram

1. **Review models in science.** Remind students that in science, a model is something that is used to help understand, predict, or explain how things work. It is like the thing it represents in some, but not all ways. The class will be exploring the Carbon Cycle Diagram on the computer as one model of the carbon cycle, and then doing another activity that uses a different model of the carbon cycle.

2. **Explore natural carbon flows on interactive diagram.** Project the "Natural Flows into Atmosphere" view of the interactive diagram, and invite students to comment on a few things they notice about this model. Click on the Volcanic Eruptions flow and point out that the information is the same as that shown on the Flow Cards, but with an animation showing the movement of carbon.

3. **Explore industrial carbon flows on interactive diagram.** Project the "Human Industry Flows" view and invite students to comment. Click on the Combustion of Fossil Fuels flow.

4. **Discuss strengths of the model.** Project the "All Flows into Atmosphere" view and ask, **"What does this model show well about the carbon cycle?"** [There are many reservoirs; carbon atoms move from one reservoir to another in many different flows.] Point out the numbers and explain that this model also shows the size of the flows and reservoirs—which ones are larger or smaller and by how much. The class will be exploring these numbers more in the next session.

5. **Discuss weaknesses of the model.** Ask, **"What does this model NOT show well about the carbon cycle?"** [Only shows two kinds of organisms; there are no ocean organisms; it looks like the carbon cycle happens in just one small place on Earth, rather than all over the planet.] Point out that with this model, you can't follow individual carbon atoms as they move through a chain of flows from reservoir to reservoir.

TEACHER CONSIDERATIONS

SCIENCE NOTES

About the Interactive Carbon Cycle Diagram. The Interactive Carbon Cycle Diagram was designed by a team of scientists and ocean educators because we could not find a carbon cycle diagram that was complete or accurate enough and also developmentally or grade-level appropriate for our purposes. We also needed it to be interactive so flows could be isolated and/or combined to see various inputs and outputs from the atmosphere. The information on each of the interactive flows and reservoirs is identical to the Carbon Cycle Cards that students use in the unit. The interactive was designed by Brian Yan under the direction of Carrie Ferraro and Kristin Hunter-Thompson from Rutgers University and Robert Rhew of University of California, Berkeley.

INSTRUCTIONAL SUGGESTIONS

Pacing: Quick Introduction to the Interactive Diagram. Unless you have extra time in this session, move quite quickly through this introduction to the Interactive Carbon Cycle Diagram. Make sure you leave enough time for the Paper Clip Carbon Cycle Models that follow. Students will be exploring the Interactive Carbon Cycle Diagram further in the coming sessions and in Unit 3. This discussion is intended to give students a little familiarity with this tool and to help reinforce the idea that every scientific model is accurate in some way(s), but inaccurate in others.

PROVIDING MORE EXPERIENCE

Reinforce: Students Explore the Interactive Carbon Cycle Diagram. If you have access to a computer for each pair of students, and if time allows, have students explore the interactive diagram on their own. Give them a few minutes to explore freely, and then pose a few focus questions. You might provide more questions than students can answer in the time provided and allow students to choose which to investigate and write about. Possible questions include:

- **Which reservoir has the most flows going into it? Why do you think that is?**
- **Do you think different parts of the ocean have different carbon flows? Why?**
- **Which two reservoirs have the biggest flows of carbon between them? Why do you think that is?**
- **What do you think would be the most important thing you could add to this diagram to make it show the carbon cycle more accurately?**

LANGUAGE OF SCIENCE

VOCABULARY

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atom
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carbon cycle
carbon dioxide/CO_2
carbon flow
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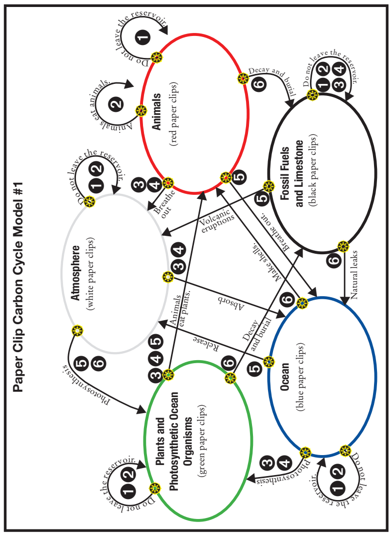
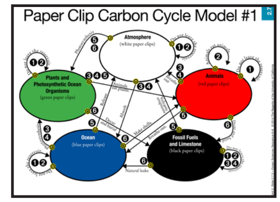


Student Sheet

Exploring Paper Clip Carbon Cycle Model

1. **Introduce Paper Clip Carbon Cycle Model.** Tell students that they will now use another model of the carbon cycle that WILL allow them to follow carbon atoms as they flow through many reservoirs.

2. **Demonstrate the model.** To demonstrate how the model works, project the student sheet for Paper Clip Carbon Cycle Model #1, using a document camera so you can set up and move the paper clips. If you do not have a document camera, project the slide of the same title onto the board and draw paper clips on the projected image, rather than using actual paper clips.

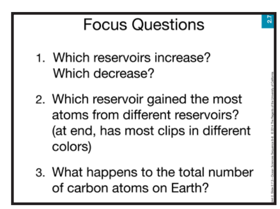


   a. **What represents what.** Point out that this model has only five carbon reservoirs, represented by the ovals on the page. The arrows between the reservoirs represent flows. Carbon atoms that belong to each reservoir are represented by different-colored paper clips, ten of each. All the paper clips represent identical carbon atoms—the different colors are so students can remember which reservoir each carbon atom started in.

   b. **Set up.** Show students how groups will place ten paper clips in each reservoir oval on the model sheet. The sheet tells which color goes with which reservoir.

   c. **Demonstrate running the model.** Say, **"Start with the ocean reservoir. One group member will roll a die. The number that comes up on the die will tell you where to move ONE carbon atom (paper clip) from that reservoir."** Demonstrate by rolling the die, then locate the number shown on the die, and match it to one of the flow arrows that exits the ocean reservoir. Move one paper clip as indicated, but note that sometimes atoms don't actually leave the reservoir. Say, **"Each group member will get one turn with the ocean reservoir, and then you will move clockwise to the next reservoir where each group member gets another turn. Continue until you've visited all five reservoirs."**

3. **Project slide; introduce focus questions.** Read aloud the focus questions and tell students to keep these in mind as they observe what happens in their model. Leave this projected as groups work.



4. **Groups set up and run the model.** Pass each group a Paper Clip Carbon Cycle Model #1 sheet, 5 small bags with the different colors of paper clips, and a die. Have groups set up their models and begin the cycle. Circulate and make sure students are running the model correctly. If a group is running it incorrectly, don't have them reset all the paper clips; have them run it correctly from that point forward.

TEACHER CONSIDERATIONS

INSTRUCTIONAL RATIONALE

Reasons for the Paper Clip Model. The goal for using this model is to help students see the way in which carbon moves around Earth as a system. Students should realize that even though the amount of carbon in one reservoir may increase or decrease, the total amount of carbon on Earth does not change. Using different colors of paper clips also allows students to observe that a carbon atom can move through many reservoirs. Students also find the model, with its elements of chance and change, to be quite engaging.

INSTRUCTIONAL SUGGESTIONS

Management of Model Materials. You may need to emphasize with your students that although this model uses a die, it is a scientific model and not a game. Dice need to be rolled quickly and quietly and in such a way that they do not fall off the desks. Groups will need to take turns, use quiet voices, and make sure all members are included.

PROVIDING MORE EXPERIENCE

Prepare: Explore the Model Sheet. Students may benefit from some time to orient themselves to the paper clip model by exploring the flows between reservoirs shown on Paper Clip Carbon Cycle Model #1. Here are a few suggested questions:

- **Where is the flow representing CO_2 moving during photosynthesis?**
- **How many different flows are there leaving the ocean?**
- **Where would you move a carbon atom if you rolled a "4" for the atmosphere?**
- **For which reservoir are carbon molecules most likely to stay put? How can you figure this out from the model?**

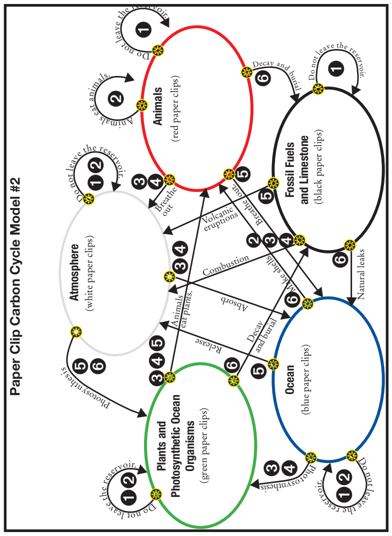
LANGUAGE OF SCIENCE

VOCABULARY

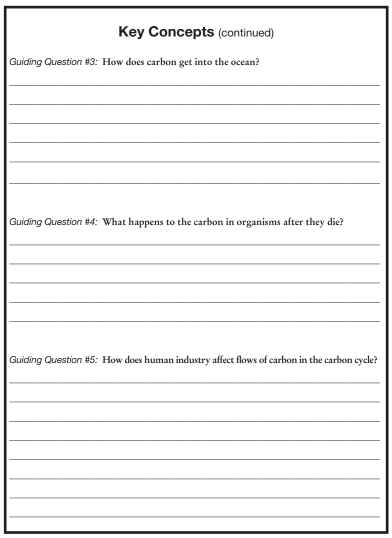
absorb
atmosphere
atom
carbon
carbon cycle
carbon dioxide/CO_2
carbon flow
carbon reservoir
combustion
decompose/decomposition
evidence
fossil fuels
matter
model
molecule
organism
photosynthesis
respiration

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?



Student Sheet


Key Concepts (continued)

Guiding Question #3: How does carbon get into the ocean?

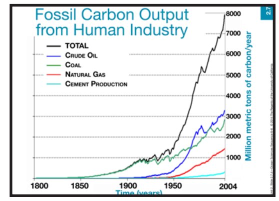
Guiding Question #4: What happens to the carbon in organisms after they die?

Guiding Question #5: How does human industry affect flows of carbon in the carbon cycle?

Investigation Notebook, p. 4

5. **Discuss focus questions as a class.** After groups run the models for about five minutes, have students set aside their materials. Discuss each of the focus questions by calling on volunteers to share. Ask,
   - **"Which reservoirs increase? Which decrease?" "What is your evidence?"**
   - **"Which reservoir gained the most atoms from different reservoirs?" "Do others agree or disagree?" "Why?"**
   - **"What happens to the total number of carbon atoms on Earth?"** [Stays the same, even if some reservoirs increase or decrease.]

6. **Project slide; discuss increasing use of fossil fuels.** Tell students that this rather complicated graph shows the increase in the combustion of various kinds of fossil fuels over the past 200 years. Have several students describe what they notice. [People are using more and more fossil fuels every year. In the 1800s, they primarily used coal; since about 1950, the use of all fossil fuels has increased rapidly.]

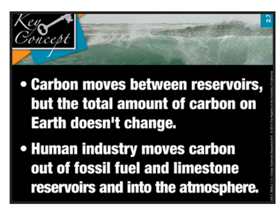


7. **Groups run Model #2 with new fossil fuels flows.** Say, **"We will use our paper clip model to investigate how this increased combustion of fossil fuels might affect the carbon cycle."** Pass each group a Paper Clip Carbon Cycle Model #2 sheet, and collect the Model #1 sheets. Point out that the new model sheet has a combustion flow from the fossil fuels reservoir. Have students set up and run the model with this sheet.

8. **Discuss results.** Call on a few volunteers to share their results with Model #2. [More carbon atoms that were originally from fossil fuels are likely to end up in the atmosphere.]

9. **Point out strengths and weaknesses of the model.** Say, **"Just like the computer model, this model shows some things well and doesn't show other things well. It is good for tracking how carbon atoms move all through the system. On the other hand, it shows far fewer flows and reservoirs, and it doesn't show that some flows and reservoirs are much bigger than others."** Have groups gather their paper clips by color, and put them back in the bags. Collect all materials.

10. **Project slide; students record key concepts.** Project the key concept slide, and have students read it. Ask students to turn to pages 3–4, Key Concepts, in their Investigation Notebooks and copy the first key concept below Guiding Question #1 and the second below Guiding Question #5.



11. **Students add to carbon cycle definition.** Have students turn to page 17, Defining the Carbon Cycle, in their Investigation Notebooks, and complete the definition by filling in the last carbon flow. [Combustion.] Ask a volunteer to read the completed definition aloud.

TEACHER CONSIDERATIONS

SCIENCE NOTES

About Global Fossil Fuel Emissions Graph. The graph in Slide 2.7.3 shows the emissions from fossil fuel burning, cement manufacture, and so on, from 1751–2008. The data was updated in June, 2011. The source is Tom Boden, Gregg Marland, and Bob Andres from the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. All emission estimates are expressed in million metric tons of carbon.

PROVIDING MORE EXPERIENCE

Reinforce: Write About Focus Questions. You could have each student write a short answer to each focus question. This will help students reflect on this model and what it shows, and increase accountability for participation in group discussions.

Reinforce: Adding Notes to First Ideas. Have students turn to page 2, First Ideas, in their Investigation Notebooks, and reread what they wrote at the beginning of the unit, considering how much they have learned since then. Next, have students add a few notes in the space provided at the bottom of the page.

Extend: Reflection Prompts for the Session.

- Which reservoirs of carbon on Earth do you think might be increasing? Which do you think might be decreasing? Why?
- Why do you think combustion of fossil fuels is increasing around the world?

LANGUAGE OF SCIENCE

VOCABULARY

absorb
atmosphere
atom
carbon
carbon cycle
carbon dioxide/CO_2
carbon flow
carbon reservoir
combustion
decompose/decomposition
evidence
fossil fuels
matter
model
molecule
organism
photosynthesis
respiration

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?

SLIDES AND PRINT MATERIALS FOR SESSION 2.7:

INVESTIGATING COMBUSTION AND THE CARBON CYCLE

Table of Contents

Slides for Session 2.7 **M2**
(5 slides to project during the lesson)

Simulation, *Interactive Carbon Cycle Diagram* **M7**
(link to versions for Mac or PC)

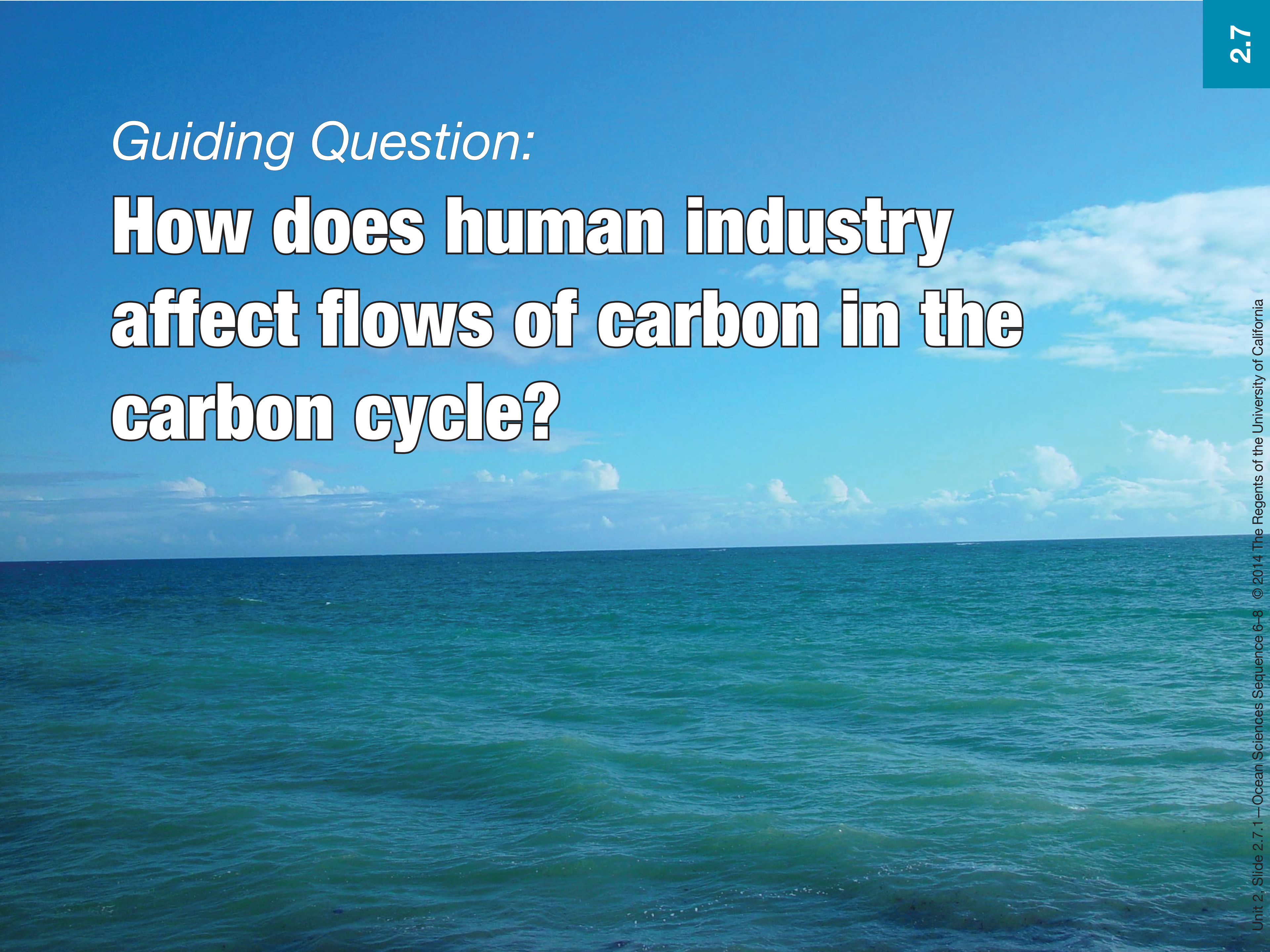
Set of Carbon Cycle Cards **M8**
(30 double-sided cards to print, one set for each group)

Paper Clip Carbon Cycle Model #1 from Copymaster Packet **M16**
(single-sided sheet to print, one for each group)

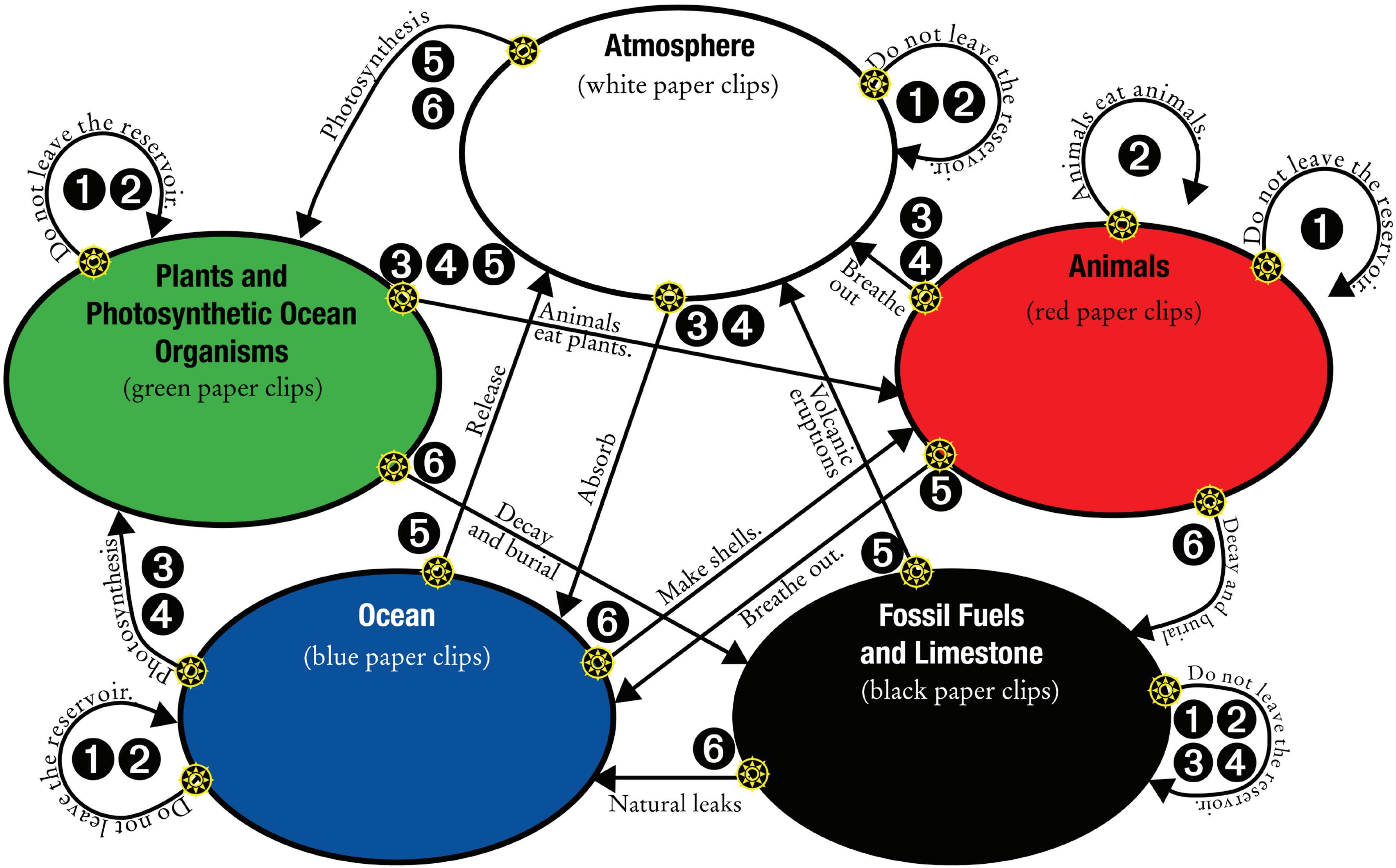
Paper Clip Carbon Cycle Model #2 from Copymaster Packet **M17**
(single-sided sheet to print, one for each group)

Student Sheets from Investigation Notebook **M18**
(print one of each sheet for each student)

- **Key Concepts, pages 3–4**
- **Defining the Carbon Cycle, page 17**


2.7
Guiding Question:
How does human industry affect flows of carbon in the carbon cycle?
Unit 2, Slide 2.7.1—Ocean Sciences Sequence 6–8 © 2014 The Regents of the University of California

Paper Clip Carbon Cycle Model #1



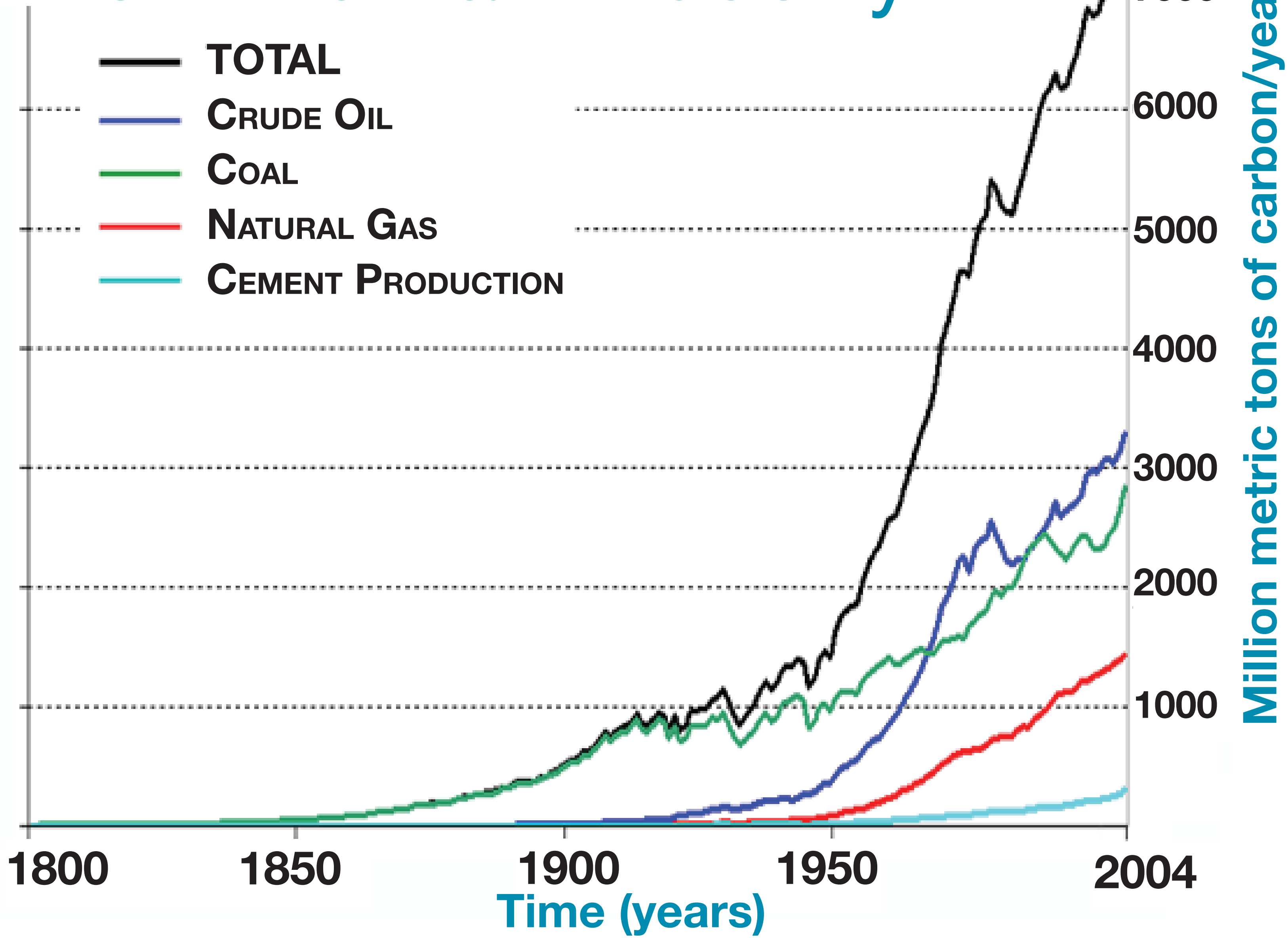
Focus Questions

1. Which reservoirs increase?
   Which decrease?

2. Which reservoir gained the most atoms from different reservoirs? (at end, has most clips in different colors)

3. What happens to the total number of carbon atoms on Earth?

Fossil Carbon Output from Human Industry



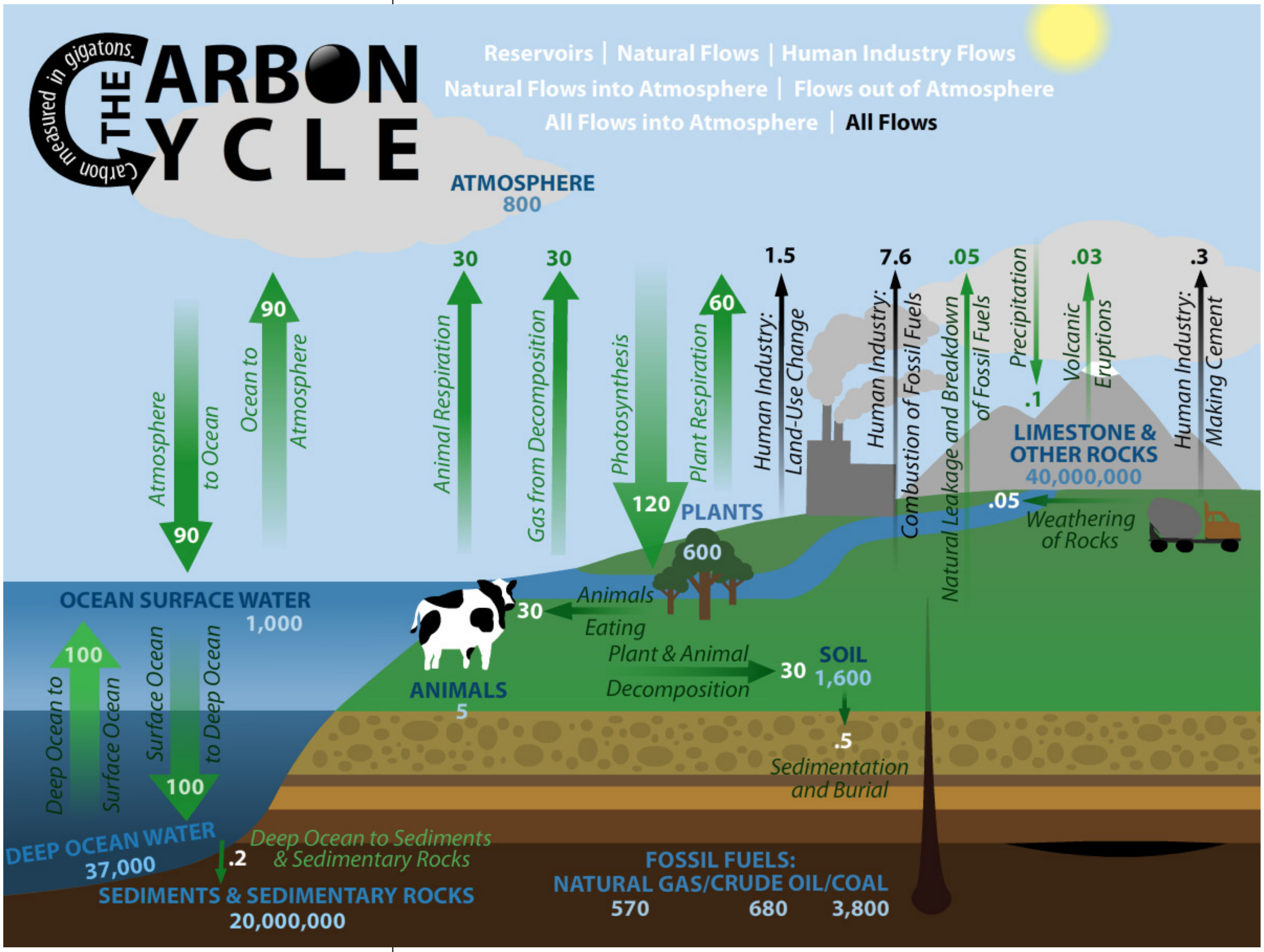
Key Concept

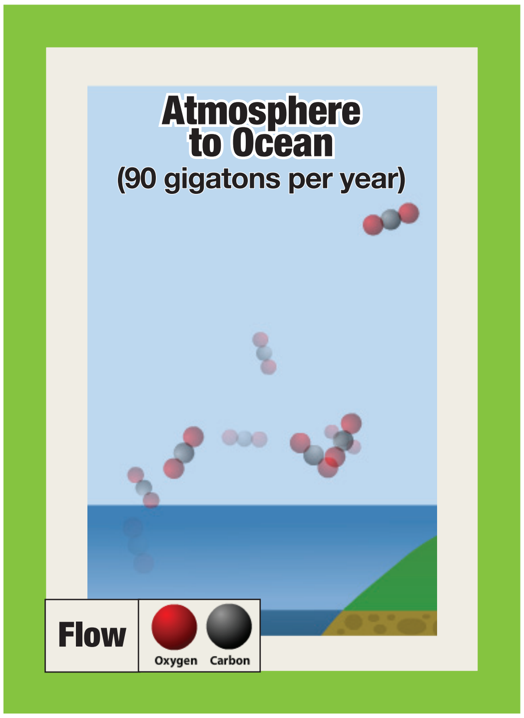
2.7

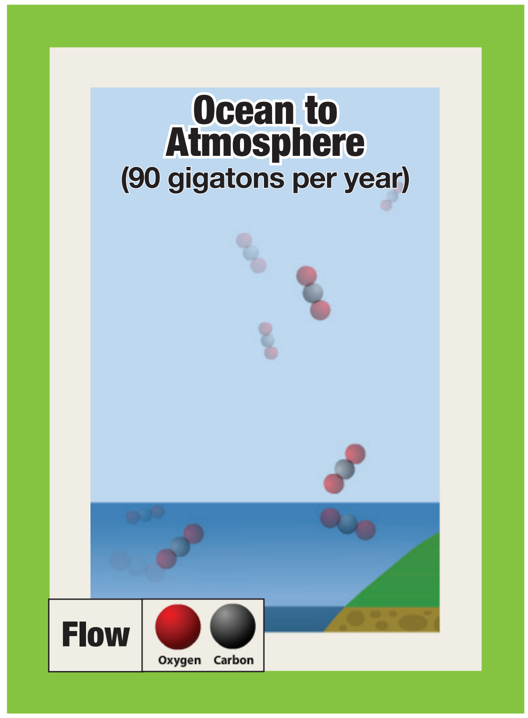
- **Carbon moves between reservoirs, but the total amount of carbon on Earth doesn't change.**
- **Human industry moves carbon out of fossil fuel and limestone reservoirs and into the atmosphere.**

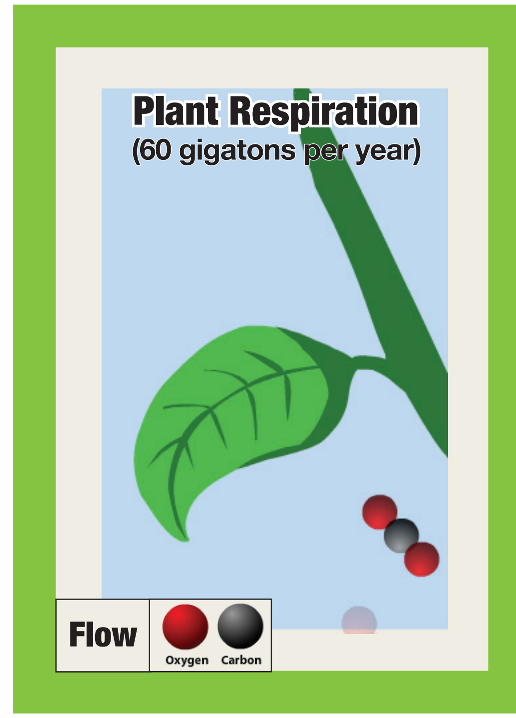
INTERACTIVE CARBON CYCLE DIAGRAM

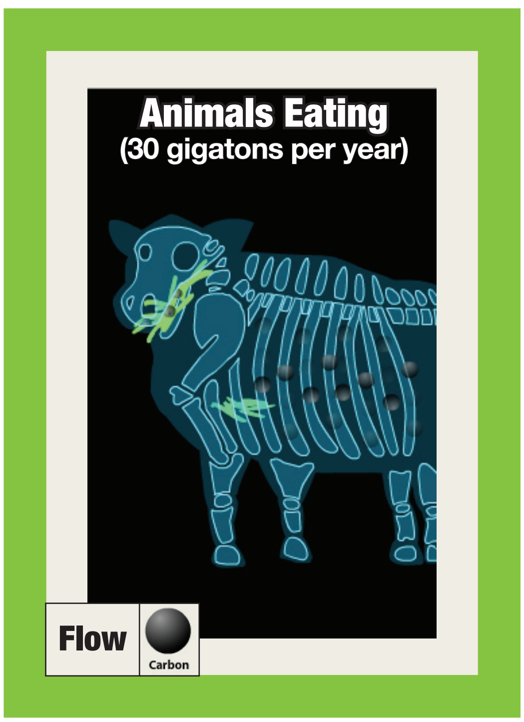
Click below for a link to resources for OSS 6-8, Unit 2.
(http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68/unit2)
Select either the Mac or PC version of the simulation for Session 2.7.
This will download the files to your computer.

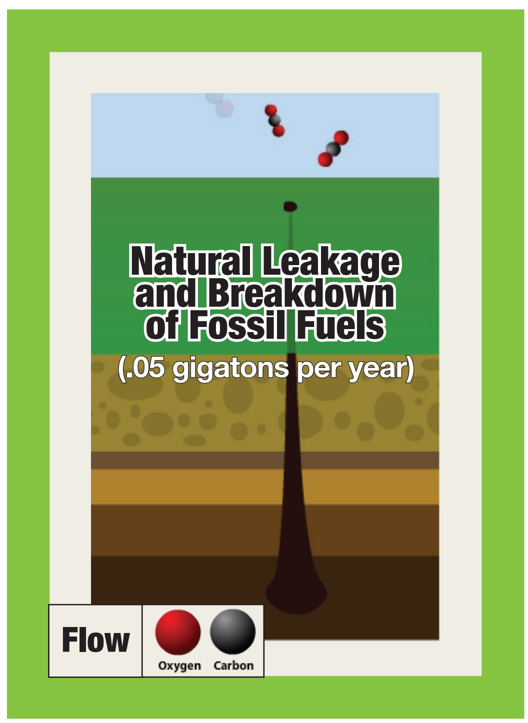



Atmosphere to Ocean
(90 gigatons per year)
Flow
Oxygen
Carbon

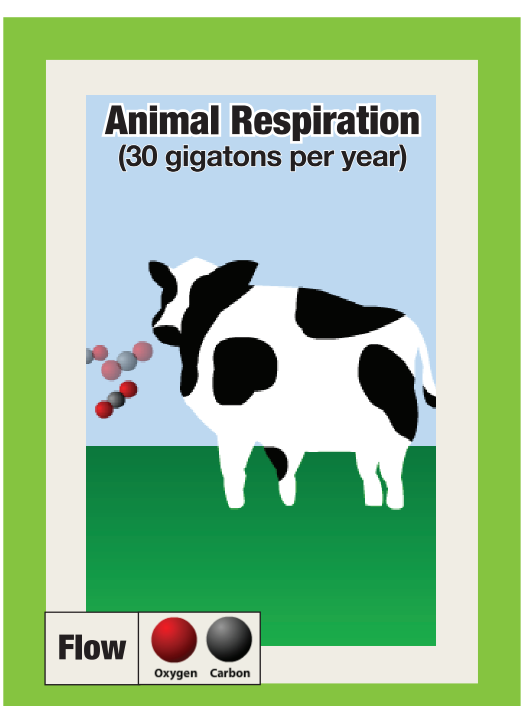

Ocean to Atmosphere
(90 gigatons per year)
Flow
Oxygen
Carbon

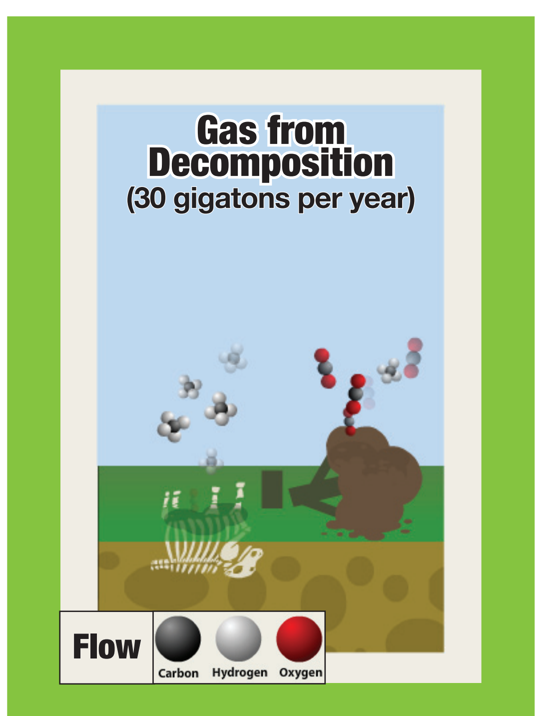

Plant Respiration
(60 gigatons per year)
Flow
Oxygen
Carbon

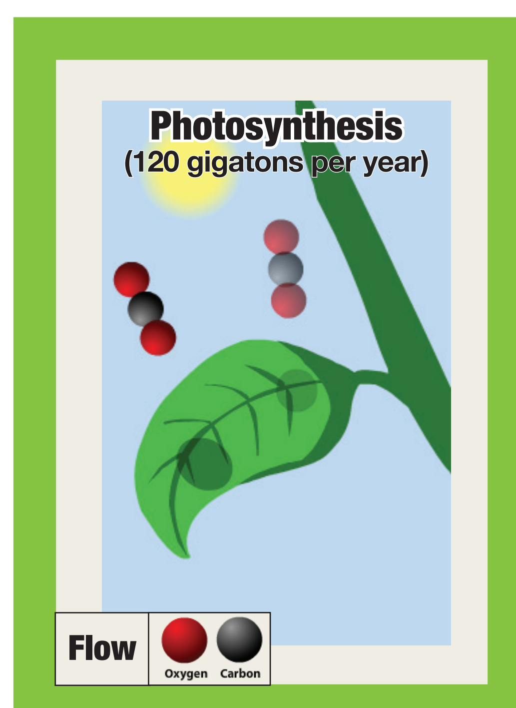

Animals Eating
(30 gigatons per year)
Flow
Carbon


Natural Leakage and Breakdown of Fossil Fuels
(.05 gigatons per year)
Flow
Oxygen
Carbon


Plant and Animal Decomposition
(30 gigatons per year)
Flow
Carbon


Animal Respiration
(30 gigatons per year)
Flow
Oxygen
Carbon


Gas from Decomposition
(30 gigatons per year)
Flow
Carbon
Hydrogen
Oxygen


Photosynthesis
(120 gigatons per year)
Flow
Oxygen
Carbon

Flow

Atmosphere to Ocean

CO_2 from the atmosphere dissolves in ocean water.

Flow

Animals Eating

Animals eat plants and/or other animals. All cells of every plant and animal contain carbon.

Flow

Animal Respiration

When animals break down the food they eat, they breathe out CO_2 into the atmosphere.

Flow

Ocean to Atmosphere

CO_2 moves out of ocean water and into the atmosphere.

Flow

Natural Leakage and Breakdown of Fossil Fuels

Small amounts of fossil fuels (natural gas, crude oil, or coal) leak from underground to the surface. At the surface, the fossil fuels naturally break down into CO_2, which flows into the atmosphere.

Flow

Gas from Decomposition

Decomposers, such as bacteria and fungi, give off carbon to the atmosphere as CO_2 or CH_4 when they break down carbon from dead animals and plants into their different nutrients.

Flow

Plant Respiration

Plants need to use up some of their sugars to survive. Plants give off CO_2 into the atmosphere as they break down their own sugars for life processes. This happens during the day and at night.

Flow

Plant and Animal Decomposition

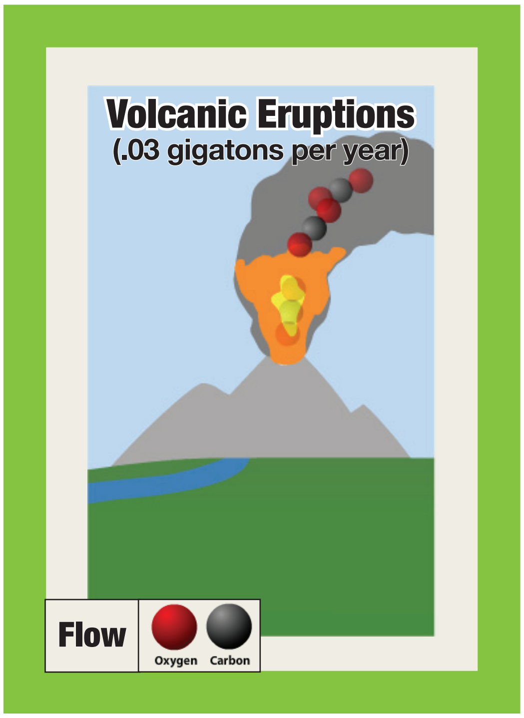
After plants and animals die, decomposers break them down into their different nutrients, which enter the soil. This is a way carbon flows into the soil reservoir.

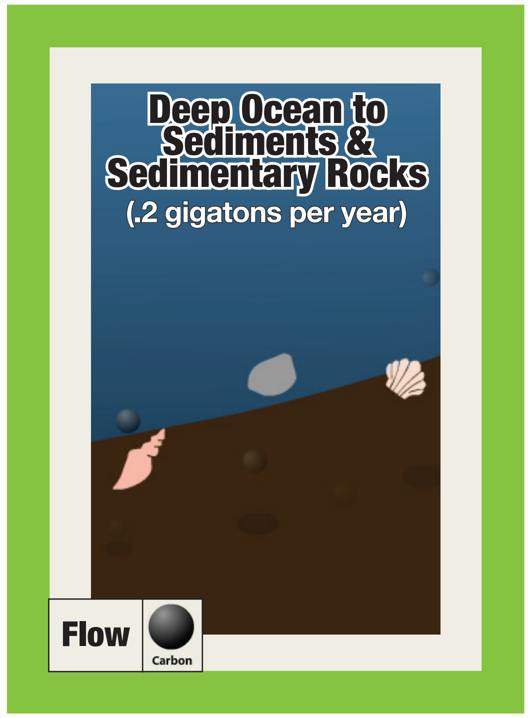
Flow

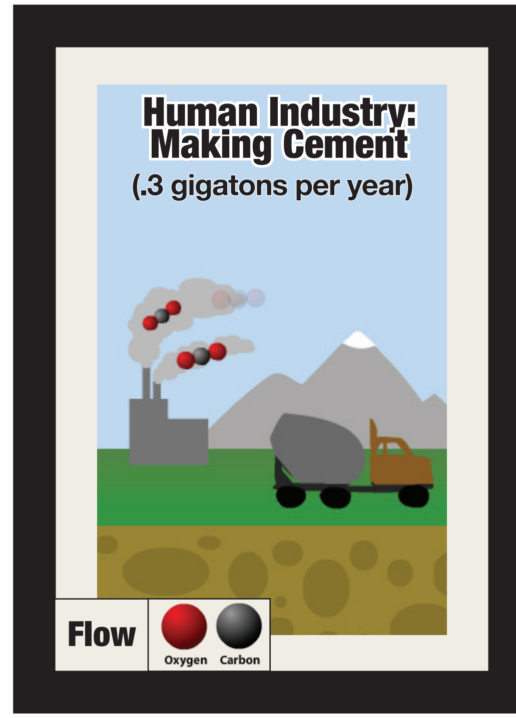
Photosynthesis

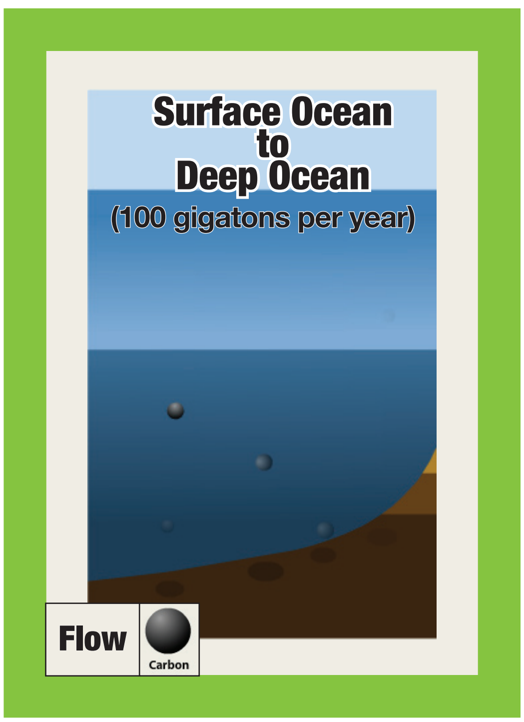
Land plants take in CO_2 from the atmosphere and H_2O from the soil to make sugars.

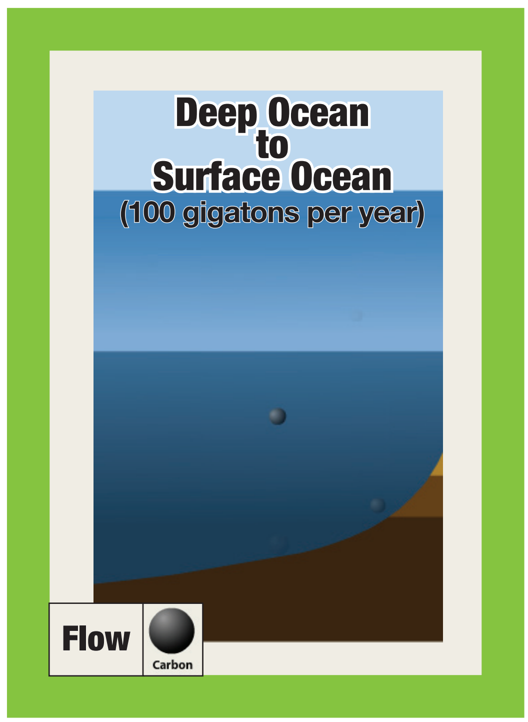
Photosynthetic organisms in the ocean take in dissolved CO_2 from the water to make sugars.

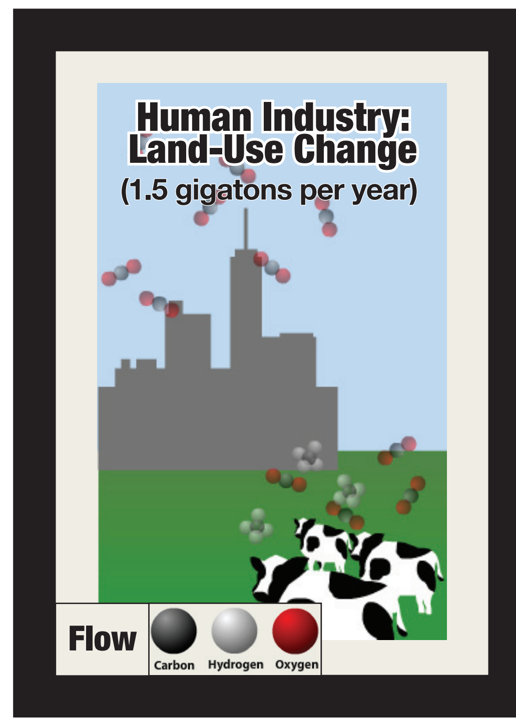

Volcanic Eruptions
(.03 gigatons per year)
Flow
Oxygen
Carbon

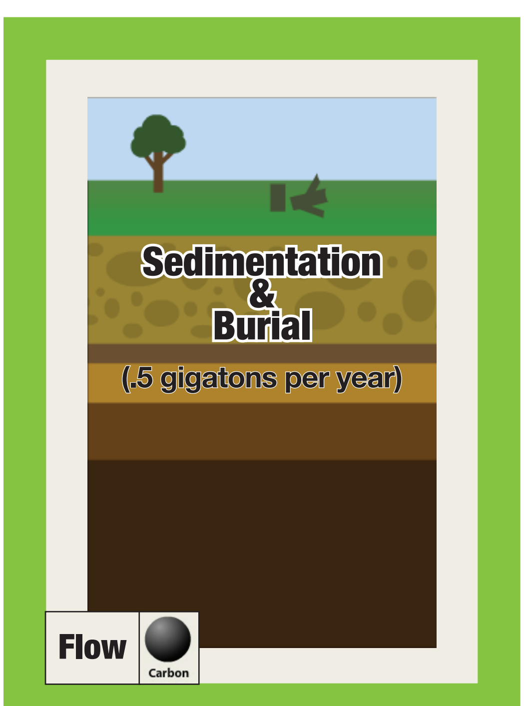

Deep Ocean to Sediments & Sedimentary Rocks
(.2 gigatons per year)
Flow
Carbon

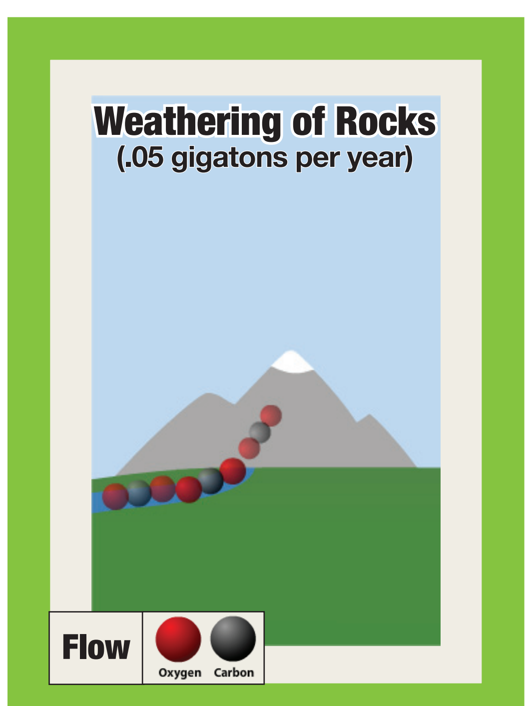

Human Industry: Making Cement
(.3 gigatons per year)
Flow
Oxygen
Carbon

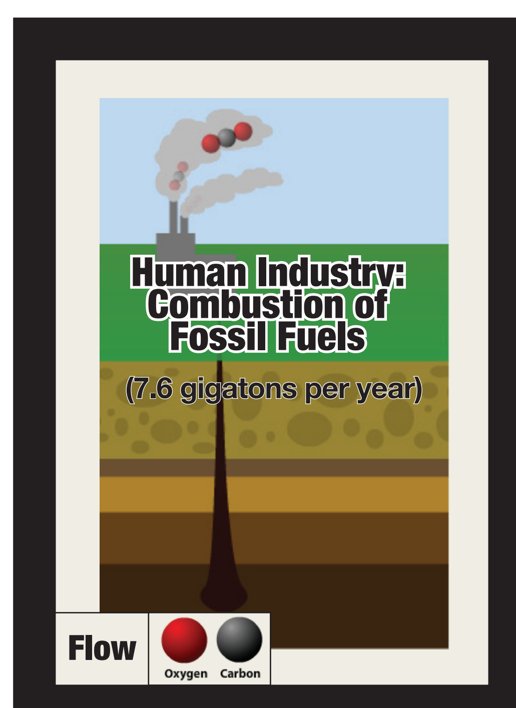

Surface Ocean to Deep Ocean
(100 gigatons per year)
Flow
Carbon


Deep Ocean to Surface Ocean
(100 gigatons per year)
Flow
Carbon


Human Industry: Land-Use Change
(1.5 gigatons per year)
Flow
Carbon
Hydrogen
Oxygen


Sedimentation & Burial
(.5 gigatons per year)
Flow
Carbon


Weathering of Rocks
(.05 gigatons per year)
Flow
Oxygen
Carbon


Human Industry: Combustion of Fossil Fuels
(7.6 gigatons per year)
Flow
Oxygen
Carbon

Flow

Volcanic Eruptions

Volcanoes release CO_2 into the atmosphere from rocks that are deep in Earth's crust.

Flow

Surface Ocean to Deep Ocean

Dead organisms, shells, and the carbon they contain, sink to deep ocean water.

Flow

Sedimentation & Burial

Carbon in the ground (originally from dead organisms), which is not consumed, can be buried under layers of earth. Under high pressures and temperatures and over millions of years, the material is changed into fossil fuels.

Flow

Deep Ocean to Sediments & Sedimentary Rocks

Dead organisms and shells settle to the seafloor. As layers build up over time, these materials may be changed into sedimentary rocks or fossil fuels.

Flow

Deep Ocean to Surface Ocean

Carbon can remain in the deep ocean for hundreds of years. However, mixing can bring deep water with carbon back to the surface.

Flow

Weathering of Rocks

Carbon from CO_2 is removed from the atmosphere when it combines with rainwater and reacts with the chemicals in rocks. The products from the reactions, such as carbonate (CO_3^{2-}), can be used by plankton or can settle on the seafloor and are eventually buried.

Flow

Human Industry: Making Cement

Limestone is heated to make cement, and this releases limestone's carbon (as CO_2) into the atmosphere. In the last ~100 years, more and more cement has been made, releasing more and more carbon as CO_2 into the atmosphere.

Flow

Human Industry: Land-Use Change

When forests are cut down or burned so the land can be used another way, such as building cities and roads or raising cows and crops, there are fewer trees to absorb carbon through the process of photosynthesis. The overall result is that more carbon ends up in the atmosphere.

Flow

Human Industry: Combustion of Fossil Fuels

In the last ~100 years, humans have taken more and more crude oil and other fossil fuels from underground and used them to power cars, machines, and more. The fossil fuels are burned, and carbon is released into the atmosphere as CO_2.

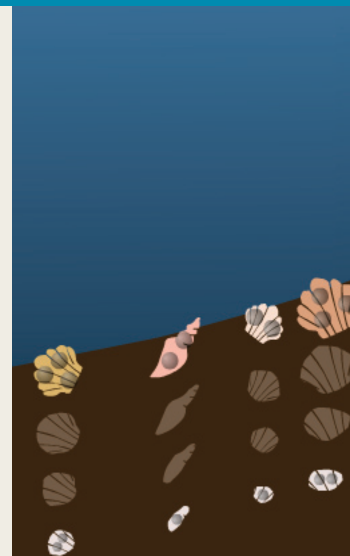
Fossil Fuels: Coal
(3,800 gigatons)

Carbon

Residence Time: 94,000 years

Limestone & Other Rocks
(40,000,000 gigatons)

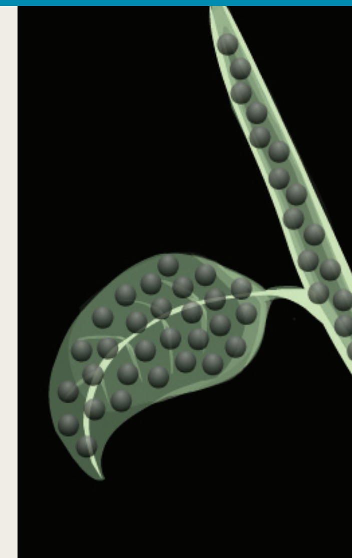
Carbon



Residence Time: 800,000,000 years

Plants
(600 gigatons)

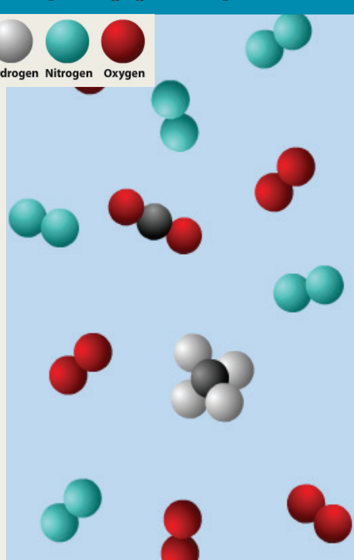
Carbon



Residence Time: 5 years

Atmosphere
(800 gigatons)

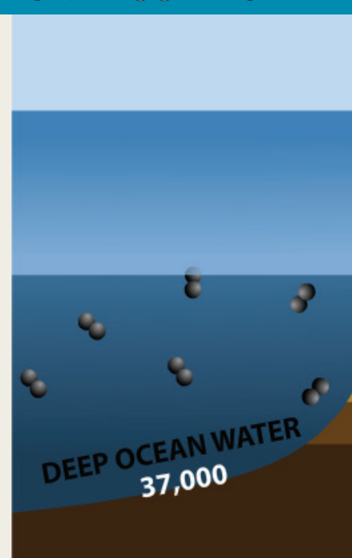
Carbon Hydrogen Nitrogen Oxygen



Residence Time: 3.6 years

Deep Ocean Water
(37,000 gigatons)

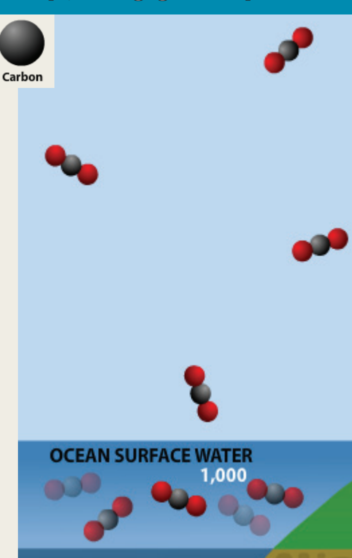
Carbon



Residence Time: 370 years

Ocean Surface Water
(1,000 gigatons)

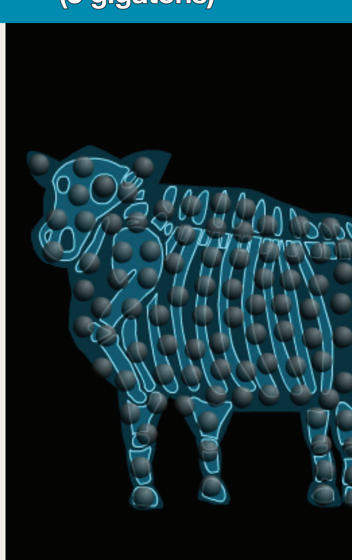
Oxygen Carbon



Residence Time: 11 years

Animals
(5 gigatons)

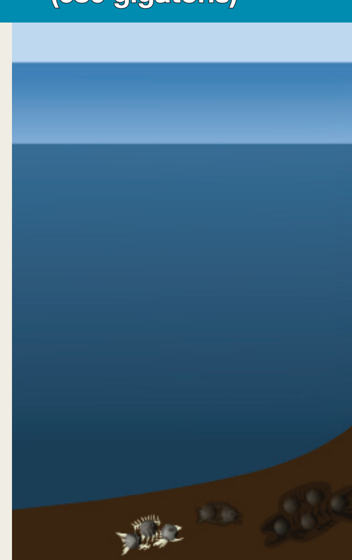
Carbon



Residence Time: 60 days

Fossil Fuels: Crude Oil
(680 gigatons)

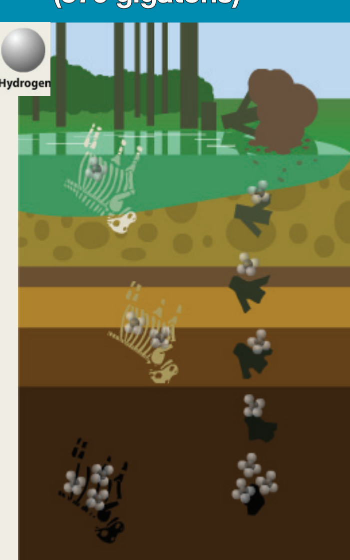
Carbon



Residence Time: 94,000 years

Fossil Fuels: Natural Gas
(570 gigatons)

Carbon Hydrogen



Residence Time: 94,000 years

Reservoir

Fossil Fuels: Coal

In watery environments on land, some dead plants get buried rather than decomposing right away. Under high pressures and temperatures and over millions of years, much of this old plant matter becomes coal.

Reservoir

Atmosphere

The atmosphere is a layer of gases surrounding the planet. The atmosphere is mostly nitrogen and oxygen gases, with less than 1% CO_2 (carbon dioxide), CH_4 (methane), and other gases.

Reservoir

Animals

Every cell in every animal has carbon in it. Animals get their carbon by eating plants or other animals.

Reservoir

Limestone and Other Rocks

Calcium carbonate ($CaCO_3$) shells from dead ocean organisms collect on the ocean floor. Over millions of years, they are buried and form limestone. Carbon in limestone may change into other rocks, such as marble.

Reservoir

Deep Ocean Water

Carbon in dead organisms slowly falls from the surface to the deep ocean (marine snow).

Reservoir

Fossil Fuels: Crude Oil

At the bottom of the ocean, some dead organisms get buried rather than decomposing. Under high pressures and temperatures and over millions of years, much of what remains of these dead organisms becomes crude oil.

Reservoir

Plants

Plants are built of sugars ($C_6H_{12}O_6$) that they make through photosynthesis, using CO_2 and H_2O. The sugars are then changed into cellulose and other materials to make different plant structures. Every cell of every plant contains carbon.

Reservoir

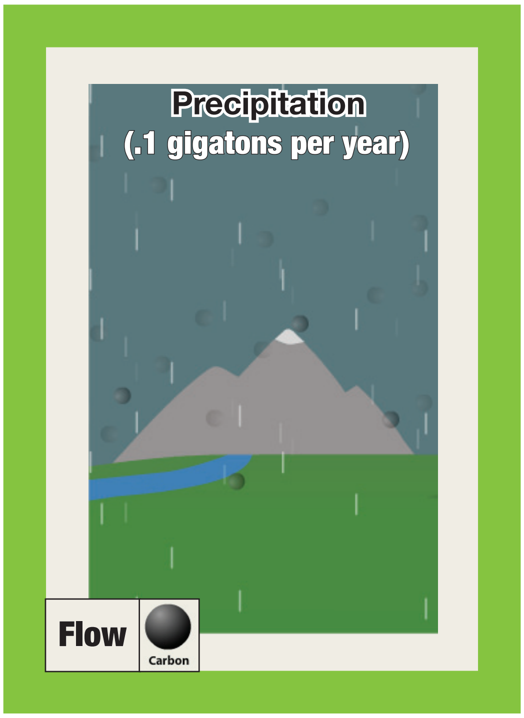
Ocean Surface Water

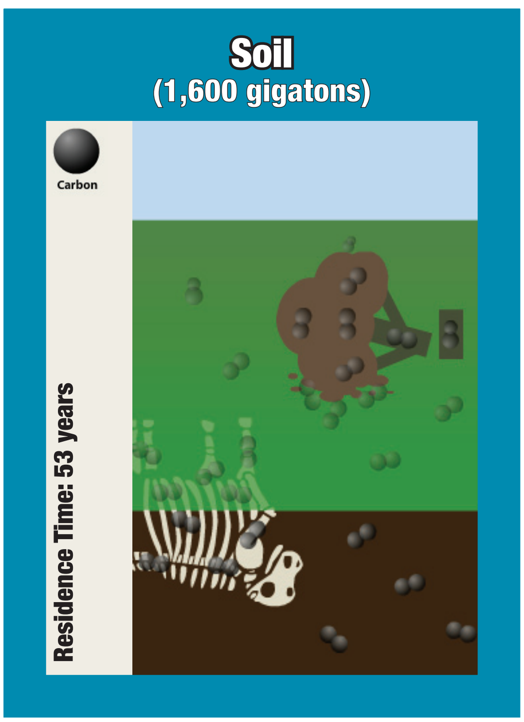
Carbon dioxide (CO_2) from the atmosphere dissolves into ocean water at the surface. Some of the carbon combines with calcium to form calcium carbonate ($CaCO_3$) in shells.

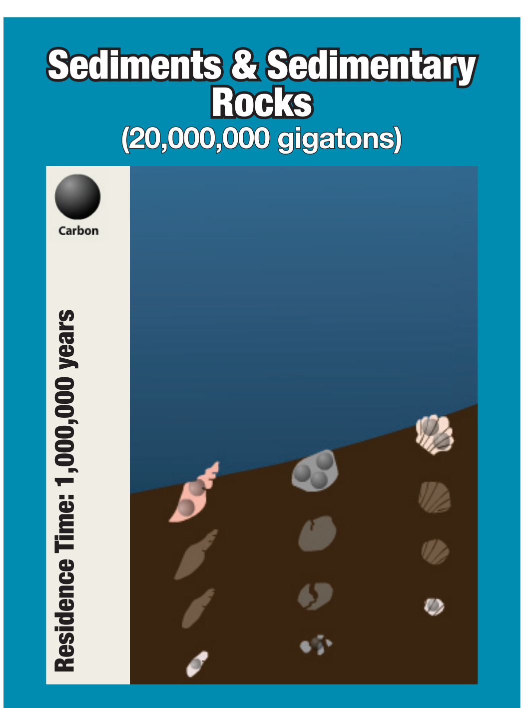
Reservoir

Fossil Fuels: Natural Gas

In watery environments on land and at the bottom of the ocean, some dead organisms get buried rather than decomposing. Under high pressures and temperatures and over millions of years, some of the buried material becomes natural gas, and the rest becomes coal or crude oil.


Precipitation
(.1 gigatons per year)
Flow
Carbon


Soil
(1,600 gigatons)
Carbon
Residence Time: 53 years


Sediments & Sedimentary Rocks
(20,000,000 gigatons)
Carbon
Residence Time: 1,000,000 years

Flow

Precipitation

As rainwater falls, it dissolves small amounts of atmospheric CO_2 to form carbonic acid (H_2CO_3). This weak acid can react with the chemicals in rocks and break them down. In some rocks, this can ultimately cause the release of carbonate (CO_3^{2-}) into the waterways.

Reservoir

Soil

Some carbon from decomposing organisms and decomposers ends up in the soil. This carbon stays in the soil for as little as a few weeks to as long as tens of thousands of years. Soil with more carbon in it is richer (more productive).

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Carbon Cycle Cards—Ocean Sciences Sequence 2.7–2.8

Reservoir

Sediments and Sedimentary Rocks

Sediments and sedimentary rocks are formed from the breakdown of rocks, such as granite and basalt, and from the buildup of dead organisms, including $CaCO_3$ shells.

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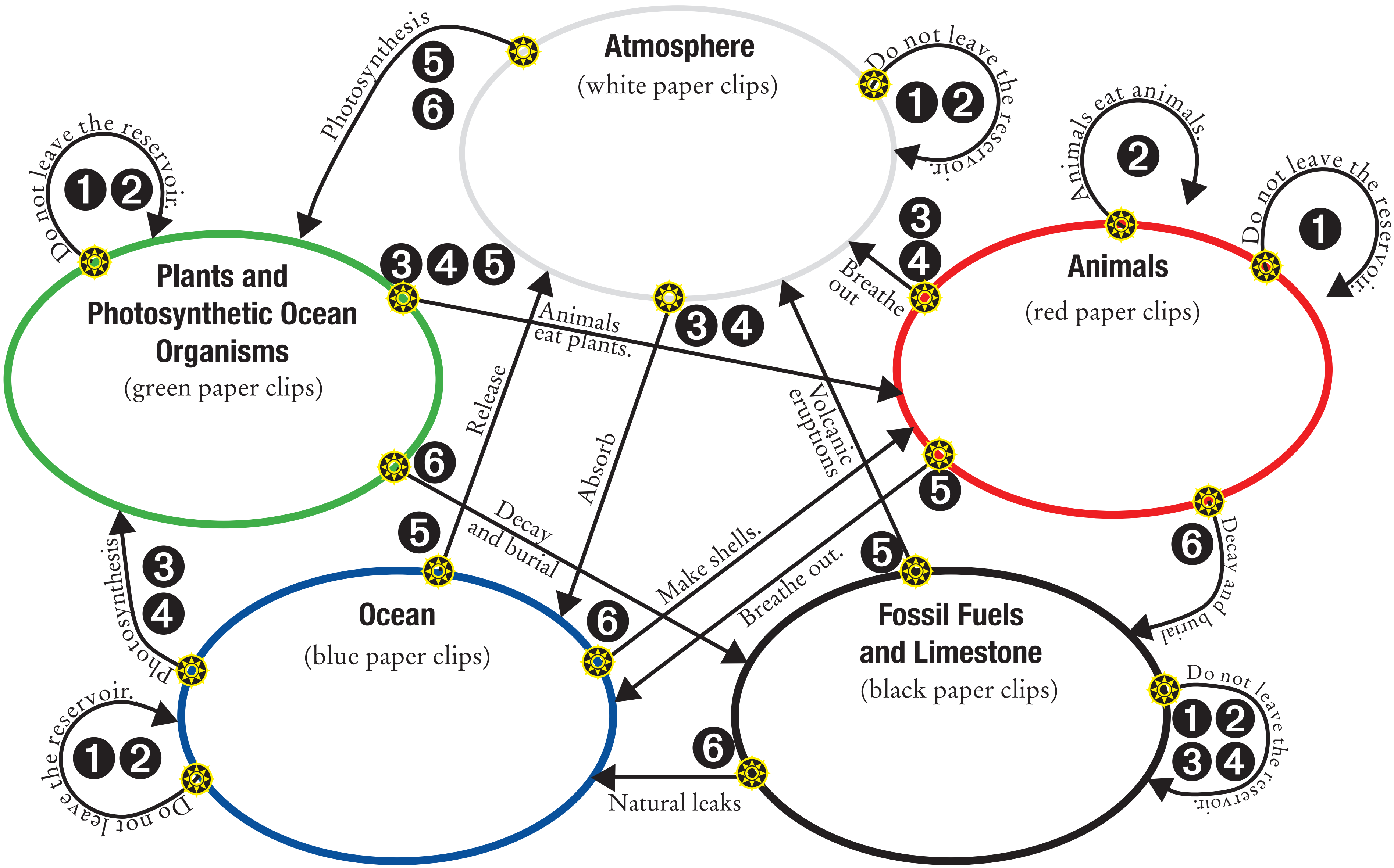
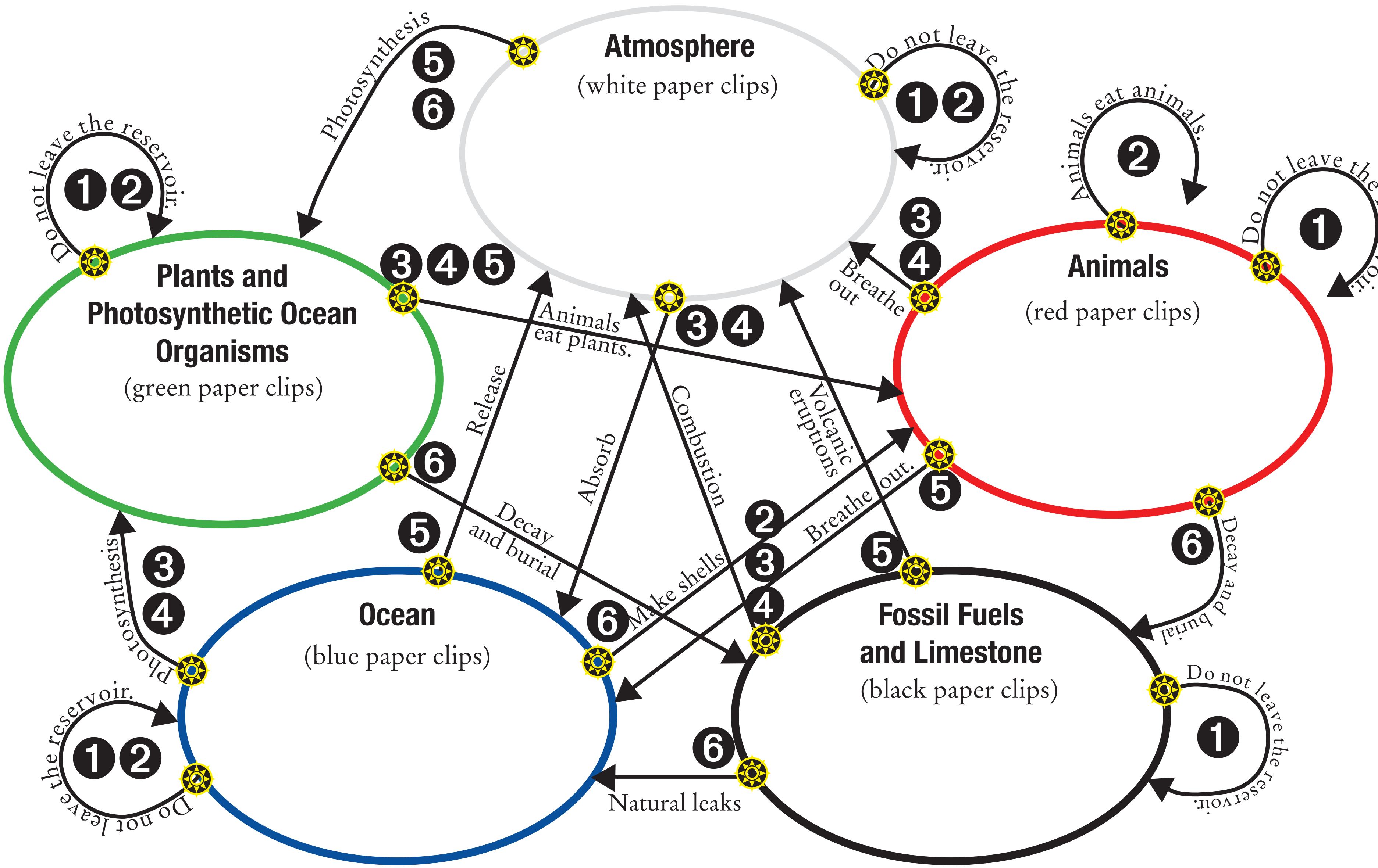
Carbon Cycle Cards—Ocean Sciences Sequence 2.7–2.8

Paper Clip Carbon Cycle Model #1



Paper Clip Carbon Cycle Model #2



Name ________________________________ Date ____________________

Key Concepts

Guiding Question #1: **Where is carbon found on Earth?**

Guiding Question #2: **How do organisms use carbon?**

Name ________________________________ Date ____________________

Key Concepts (continued)

Guiding Question #3: **How does carbon get into the ocean?**

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Guiding Question #4: **What happens to the carbon in organisms after they die?**

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Guiding Question #5: **How does human industry affect flows of carbon in the carbon cycle?**

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Name ________________________________ Date ____________________

Defining the Carbon Cycle

Simple Definition:

The whole system of flows of carbon between different parts of Earth is called the carbon cycle.

More Complete Definition:

Living things take in carbon as CO_2 through the process of ____________________

and return carbon to the environment through the processes of

(*a*) ______________________________ , (*b*) ______________________________ ,

(*c*) ______________________________ , (*d*) ______________________________ ,

and

(*e*) ______________________________ . *This is the carbon cycle.*