Smithsonian | SCIENCE *for Global Goals*

# OCEAN!

## Part 3:

### Ocean and Air

SUSTAINABLE DEVELOPMENT GOALS

developed by
Smithsonian Science Education Center

in collaboration with
iap SCIENCE HEALTH POLICY
the interacademy partnership

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# PART 3: OCEAN AND AIR



Part 3

***Find out More!***

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

# Planner

| Activity | Description | Materials and Technology | Additional Materials | Approximate Timing | Page Number |
|---|---|---|---|---|---|
| **Task 1: How do ocean systems help regulate Earth's air?** | | | | | |
| ***Discover*** | Connect with your breath and the ocean through mindfulness, and examine data about oxygen production on Earth. | • Paper<br>• Pen or pencil | *Ocean Identity Map* | 20 minutes | 85 |
| ***Understand*** | Learn about the carbon cycle, examine data about atmospheric carbon, and investigate blue carbon sinks. | • Paper<br>• Pen or pencil<br>• Blue Carbon Game cards<br>• Scissors<br>• Colored tape (optional)<br>• 2 sets of 20 small items each—paper clips, small stones, blocks, etc. | *Ocean and Air System Diagram*<br>*Ocean Identity Map*<br>*Notice, Think Wonder* | 40 minutes | 89 |
| ***Act*** | Consider different perspectives on ways to take action to reduce carbon dioxide in the air. | • Paper<br>• Pen or pencil | *Ocean and Air System Diagram*<br>*Ocean Identity Map* | 15 minutes | 101 |

Part 3 Planner

 

| Activity | Description | Materials and Technology | Additional Materials | Approximate Timing | Page Number |
|---|---|---|---|---|---|
| **Task 2: How can we prevent ocean acidification?** | | | | | |
| ***Discover*** | Reflect on carbon dioxide emissions from your community and investigate how carbon dioxide in the air leads to ocean acidification. | • 4 clear plastic or glass cups (5 if doing options 1 and 2)<br>• Markers<br>• Natural pH indicator (such as red cabbage, blueberries, raspberries, blackberries, grapes or plums) and boiling water and a strainer, or pH meter or strips<br>• Acid, such as vinegar or lemon juice<br>• Base, such as baking soda<br>• For option 1: straw<br>• For option 2: foil, plastic wrap (cling film) | *Ocean and Air System Diagram* | 45 minutes | 104 |
| ***Understand*** | Investigate the impact of an acidifying ocean on the shells of ocean organisms. | • 5 shells (such as oyster, mussel, or egg)<br>• 5 clear glass or plastic cups<br>• Small digital scale (optional)<br>• Markers<br>• Acid, such as vinegar or lemon juice<br>• Water | *Ocean Identity Map*<br>*Ocean and Air System Diagram* | 30 minutes + overnight + 15 minutes | 110 |
| ***Act*** | Find consensus and take action on ocean acidification. | • Paper<br>• Pen or pencil | *Ocean Identity Map*<br>*Ocean and Air System Diagram* | 25 minutes + action time | 113 |

Part 3 Planner

 

### *Meet Your Research Mentor*

Meet Dr. Rebecca Albright. Rebecca (pronounced *Ruh-BEH-kah*) will be your research mentor to help you understand more about the system of Earth's ocean and air.

Rebecca is a curator at the California Academy of Sciences. She studies ocean acidification and its impact on coral reefs. She also co-leads the Academy's Hope for Reefs initiative. Rebecca has a doctoral degree in marine biology and fisheries. However, she also has knowledge and perspectives that come from other parts of her identity. Since Rebecca is now working with you, it is important to understand who she is.

### *Rebecca's Identity Map*

- Female
- Has one big sister
- Mom of two—a girl and a boy
- Has one cat named Mochi
- Likes to paint
- Loves being outdoors (hiking, etc.)
- Grew up in Ohio
- Curator at the California Academy of Sciences
- Lived in Australia for three years
- Loves to salsa dance (and just dance in general)
- Favorite colors are purple and green
- Taught at a bilingual school in the Dominican Republic

Part 3

 

# Task 1: How do ocean systems help regulate Earth's air?

Some people call the ocean the "lungs of the Earth." But unlike human lungs (which take in oxygen and produce carbon dioxide), the ocean takes in carbon dioxide and produces oxygen. In this task you will ***discover*** more about the connections between the air in your community and the ocean. Then you will investigate to ***understand*** the processes of the ocean involved in this relationship with Earth's air. Finally, you will ***act*** to make people a more positive part of this system.

Before you begin the rest of Part 3, think quietly to yourself about Rebecca's identity map and compare it to your *Personal Identity Map*.

- Are there things you have in common with Rebecca?
- Are there ways in which you are different from Rebecca?
- Can you see anything about Rebecca's identity that relates to understanding the system of the ocean?

Throughout Part 3 you will notice Rebecca sharing ideas and experiences with you. She may help you understand better ways to do your research or share some of the research she has done.

***Discover:*** *How does air connect my community and the ocean?*

The **atmosphere** is the mixture of gases that surround Earth. Billions of years ago, there was almost no oxygen in Earth's atmosphere. Over time, the process of **photosynthesis** evolved in ocean organisms called **cyanobacteria**, which are also called blue-green algae. Photosynthesis is now used by plants, algae, and some species of bacteria. Photosynthesis takes in carbon dioxide and produces oxygen. Through the process of photosynthesis, the oxygen that is part of Earth's atmosphere has increased over time.



 

Today, around 21% of Earth's atmosphere is oxygen. This oxygen is essential for the survival of most organisms on Earth, including people. We breathe in air from the atmosphere. As we take in oxygen, we produce carbon dioxide. This is the opposite of what happens during photosynthesis.

There is one atmosphere, just like there is one ocean. The oxygen, carbon dioxide, and other gases produced in different parts of the planet all mix together, much like the water of the ocean mixes over time. In this activity you will be thinking about the system and the balance between oxygen and carbon dioxide in the air and in the ocean.

1. Find a comfortable place to sit.
2. Have one person, such as a teacher or a teammate, slowly read aloud *Mindfulness: Breathing with the Ocean*. Follow the instructions.



### ***Mindfulness: Breathing with the Ocean***

Relax your body and close your eyes.

Breathe in deeply and then breathe out. As I talk, keep breathing in and out at a pace that is comfortable for you.

Breathe in, imagining the air flowing into your lungs from the space around you. Imagine oxygen from that air entering your body through your lungs.

Find gratitude for the oxygen that allows your body to work.

Imagine the carbon dioxide your body produces exiting your body through your lungs. You do not need it. Breathe it out.

Think of the nearest plant. It may be a tree, a blade of grass, a vine, a bush, or even what is sometimes called a weed. Imagine that green plant taking in your carbon dioxide and letting out oxygen. Breathe in the oxygen from the plant. Breathe out the carbon dioxide the plant uses. Take a few breaths, imagining the balance between you and the plants around you.

Go farther in your mind to the edges of your community. Imagine all the plants of your community taking in carbon dioxide and producing oxygen, and all the people and other animals in your community breathing in oxygen and letting out carbon dioxide. In and out. In balance. The air is mixing. There are no edges. There are no boundaries.

Now send your mind all the way to the ocean. About half of the oxygen produced on Earth comes from the ocean. Imagine the seagrasses, mangroves, and kelp forests of the ocean. Breathe in the oxygen they produce. Breathe out the carbon dioxide they use.

Imagine the **plankton**—the algae, the drifting plants, the bacteria. They are producing more oxygen than anything else on Earth. Breathe in the oxygen they give. Find gratitude for the life-giving oxygen produced by something too small to see.

Breathe in and out a few more times. Imagine slowly bringing your breath back—first to your community, then to the nearest plant, and finally to the place where you began—you. Find gratitude for the balance of the system where some living things need oxygen and produce carbon dioxide, and some living things need carbon dioxide and produce oxygen. You are part of this system.

Open your eyes when you are ready.

3. Take out a piece of paper and label it "Ocean and Air System Diagram."
4. Consider the elements in the system of Earth's air you just thought about. You can go back and read *Mindfulness: Breathing with the Ocean* again if you need to remind yourself. Think about people, other living things in your community, and other living things in the ocean.
5. For each element you thought about, write down its name and draw a box around it. Be sure to include people. Also include at least one other living thing from your community and at least two other living things from the ocean, including plankton. Figure 3.1 shows an example of a system diagram, if you need help.



 

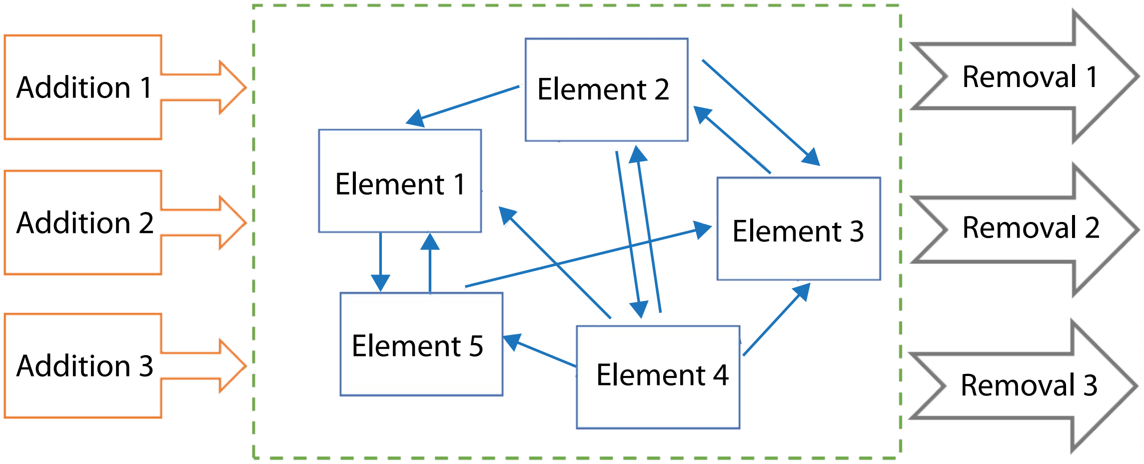


*Figure 3.1: Sample system diagram including elements, relationships, boundary, Additions, and Removals.*

6. Think about how oxygen moves between the elements in your system. Draw and label arrows to show that movement.
7. Think about how carbon dioxide moves between the elements in your system. Draw and label arrows to show that movement.
8. Turn to a partner and discuss: Why might it be important that some living things produce carbon dioxide and some living things produce oxygen?
9. Examine the pie chart in Figure 3.2.

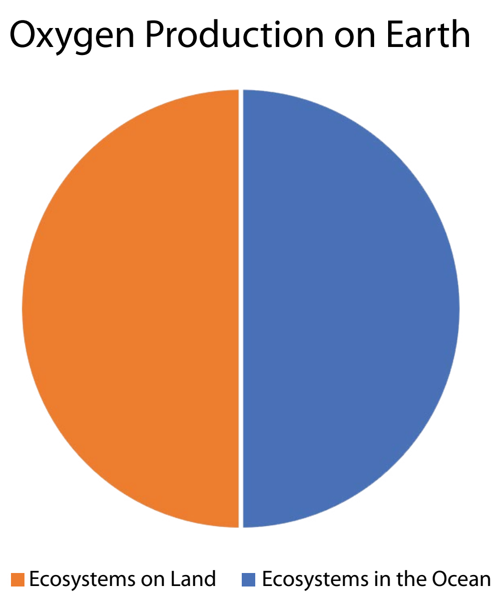


*Figure 3.2: This chart shows the contribution of land and ocean ecosystems to Earth's oxygen production.*

10. As a team, take out a piece of paper or use a class board and divide it into three columns. Label these columns "Notice," "Think," and "Wonder."

11. As a team, discuss the following questions and record your answers.
    a. Notice: What do you notice about Figure 3.2? Are there things that surprise your or seem important? Record your ideas in the *Notice* column.
    b. Think: Why do you think it is important to know about which types of ecosystems produce oxygen? Do you think there are important elements from Figure 3.2 that are missing from your *Ocean and Air System Diagram*? Record your ideas in the *Think* column. Add any important missing elements to your *Ocean and Air System Diagram*.
    c. Wonder: What does Figure 3.2 make you wonder? For example, does it make you wonder things about the system of the air and the ocean, or wonder about what might happen to our atmosphere if there were fewer things producing oxygen? Record your ideas in the *Wonder* column.
12. Read Rebecca's thoughts about the connections between people, the atmosphere, and the ocean.

***Rebecca says . . .***

About half of the oxygen we breathe (every other breath you take) comes from the ocean—mostly from tiny, microscopic algae, or **phytoplankton**, which photosynthesize, turning carbon dioxide, sunlight, and water into food and releasing oxygen in the process.

13. Take out your *Ocean Identity Map*. Think about what you have learned about the connection between the air you breathe and the ocean. Add words, images, drawings, or something else to represent that connection in the *Connections* circle.

***Understand:*** *What is the role of the ocean in Earth's carbon and oxygen cycles?*

Photosynthetic organisms in the ocean produce oxygen, which cycles between the air and other organisms in the ocean and on land. Carbon also cycles between the air and many different **carbon sinks**, which are environments or living things that store carbon. The biggest carbon sink on Earth is actually the water of the ocean. You will learn more about this in Task 2. The living things of the ocean are also important carbon sinks. In this activity you will investigate more about the recent changes to Earth's **carbon cycle**. You will also think about the role the ocean ecosystems play in the carbon cycle.

1. Take out your *Ocean and Air System Diagram* and draw a circle around your existing elements. Label this circle "living things."
2. Add four new elements—"ocean," "land," "air," and "fossil fuels"—around the *living things* circle.
3. Read *The Carbon Cycle,* and each time you notice ways carbon moves between *ocean*, *land*, *air*, *living things*, and *fossil fuels,* draw and label arrows in your *Ocean and Air System Diagram* to show that movement.

## *The Carbon Cycle*

The carbon cycle is the cyclical movement of different forms of carbon between organisms, the ocean, the land, and the air. Figure 3.3 is an illustration of the carbon cycle.

All organisms are made out of molecules that contain carbon. Each living thing acts as a carbon sink. When organisms die and decompose, usually this carbon is released back into the air as carbon dioxide. Some carbon dioxide stays in the air and some carbon dioxide dissolves in the water of the ocean.

However, sometimes the carbon from living things is buried under the land or the ocean. If living things are isolated from air, they may not **decompose**, especially if they are buried underwater. This is called **carbon storage**. Over millions of years, heat and pressure can transform buried carbon into **fossil fuels** such as petroleum (oil), natural gas, and coal. Petroleum and natural gas were generally formed when plankton from the ocean died and was buried by **sediments** on the ocean floor. Coal was generally formed when plants and animals in swamps died and were buried by sediments on the swamp bottom. Even though these fossil fuels were formed in the ocean or swamps, today the places where they are found might be very different, such as dry land or even desert.

The carbon in fossil fuels has been locked away from Earth's atmosphere for millions of years. However, over the past 150 years or so, people have started using a lot of these fossil fuels as sources of energy. When fossil fuels are burned, they release a lot of energy that can be used to do things such as power a car, create electricity, or heat a home. Burning fossil fuels also releases carbon dioxide and other **greenhouse gases** into the atmosphere. These released gases are called **emissions**. Greenhouse gases are gases such as carbon dioxide and methane that trap heat and cause the atmosphere to get warmer. You can go to the *Energy!* guide if you would like more information about fossil fuels and other potential sources of energy.

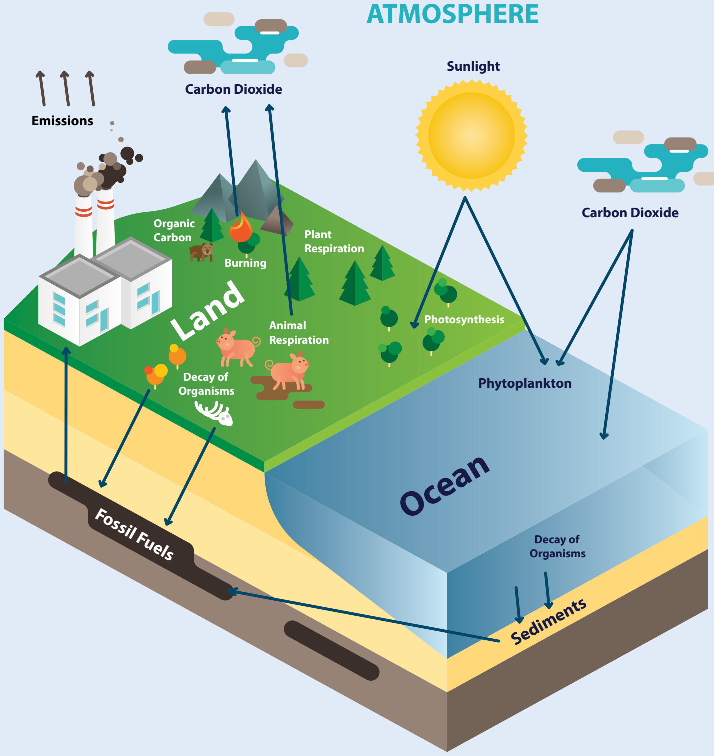


*Figure 3.3: The carbon cycle.*

4. Turn to a partner and compare your *Ocean and Air System Diagrams*. Can you both trace the way carbon moves between *living things*, *air*, *land*, *ocean*, and *fossil fuels*? Help each other make sure you both have the whole carbon cycle. Go back and read *The Carbon Cycle* again if you have questions.

Part 3 Task 1

 

5. Examine the graph in Figure 3.4, which shows atmospheric carbon dioxide (the blue line) and carbon dioxide emissions (the orange line) between the years 1750 and 2020.

**Global Atmospheric Carbon Dioxide Compared to Annual Emissions (1751-2022)**

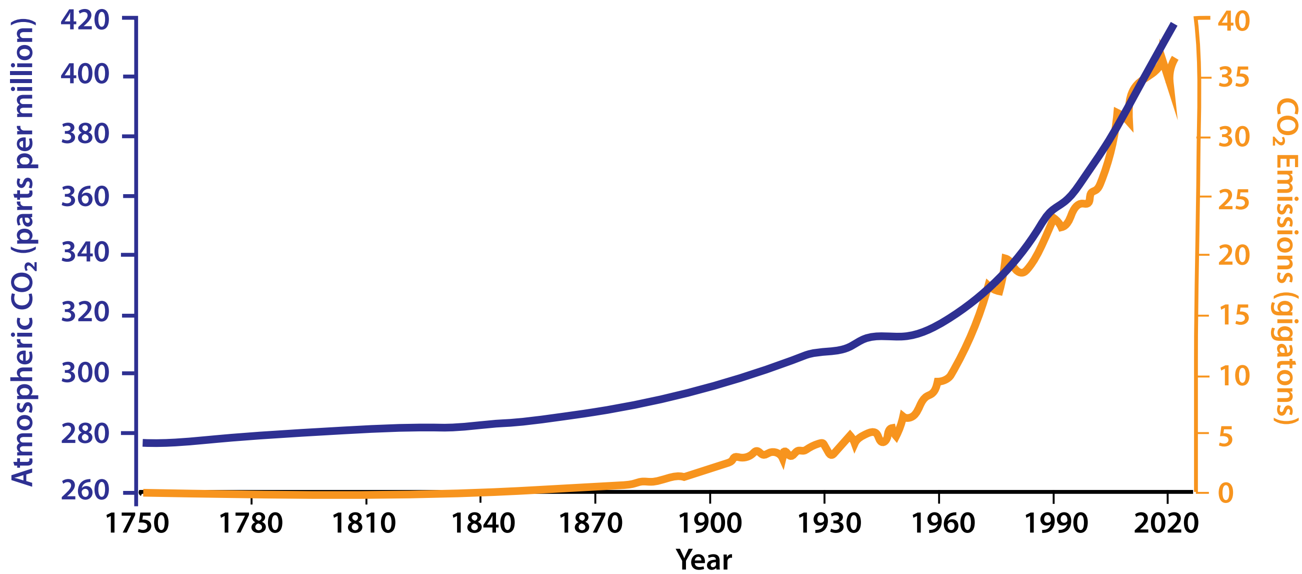


*Figure 3.4: The change in atmospheric carbon dioxide over time*[1].

6. Take out your <u>*Notice, Think, Wonder*</u> sheet from the Discover activity and use it to answer these questions.
   a. In the *Notice* column record your answers to these questions:
      - What do you notice about carbon dioxide ($CO_2$) emissions from 1750 to 2020 (orange line)?
      - What do you notice about atmospheric carbon dioxide ($CO_2$) from 1750 to 2020 (blue line)?
      - What do you notice about the relationship between those two lines?
   b. In the *Think* column record your ideas about the impact of additional atmospheric carbon dioxide. This atmospheric carbon dioxide is a new *Addition* to the ocean and air system. What do you think might change in the system as the amount of atmospheric carbon dioxide increases? Use the *elements* and *relationships* in your <u>*Ocean and Air System Diagram*</u> to help you think.
   c. In the *Wonder* column record your thoughts about what Figure 3.4 makes you wonder. For example, do you wonder about where the increase in carbon dioxide is coming from or what it will mean for the planet?



 

14. Read *What Is Blue Carbon?*

## *What Is Blue Carbon?*

As you learned, through the carbon cycle plants take in and store carbon dioxide. When these plants die, usually the carbon in them is returned to the atmosphere as they decompose.

However, something special happens in coastal wetlands such as mangroves, seagrass beds, and salt marshes. There is a lack of oxygen in the coastal sediment. That means the carbon in the plants and other organisms often does not actually decompose and instead stays buried in the mud for hundreds or even thousands of years. When comparing the same size area, these types of ecosystems can be even better than forests on land at storing carbon. This ocean carbon storage is sometimes called **blue carbon**.

*Figure 3.5: Mangroves below and above the water line.*

There is a problem, though. If these ecosystems are disturbed or destroyed, they have the potential to quickly release a lot of carbon back into the atmosphere. This is sometimes called a **carbon bomb**.

15. Prepare to play the Blue Carbon Game by making the cards you will need. You can print the cards in Figure 3.6. If you do not have a printer, make the cards by writing the words on a piece of paper or cardboard. Cut the cards apart so you have 15 separate cards.

Part 3 Task 1

| | | |
|---|---|---|
| You want to build a shrimp farm. You can choose to:<br>Use: **2 mangrove spaces**<br>Earn: **+2 people points** | Mangroves are a great place for baby fish to grow. This helps local people who fish.<br>If there are at least 3 mangroves on the board:<br>Earn: **+2 people points** | You want to build a new resort. You can choose to:<br>Use: **3 connecting spaces (can be mangrove or empty)**<br>Earn: **+3 people points** |
| You want to build a shrimp farm. You can choose to:<br>Use: **1 mangrove space**<br>Earn: **+1 people point** | Mangroves make excellent charcoal. You can choose to:<br>Use: **1 mangrove space**<br>Earn: **+1 people point** | You love being near the ocean and want to build a home there. You can choose to:<br>Use: **2 connecting spaces (can be mangrove or empty)**<br>Earn: **+2 people points** |
| You manage coastal restoration for your local government. Some people want mangroves preserved, but that makes others unhappy. You can choose to:<br>Change: **1 empty or built space to a mangrove**<br>Earn: **0 people points** | You are an ecologist working to restore mangroves. You can choose to:<br>Change: **1 empty or built space to a mangrove**<br>Earn: **+1 people point** | You are an environmental activist working to restore balance. You can choose to:<br>Change: **1 empty or built space to a mangrove**<br>Earn: **+1 people point** |
| You run an ecotourism company helping tourists explore the mangroves.<br>If there are at least 3 mangroves on the board:<br>Earn: **+2 people points** | Businesses in your area are producing more and more goods, but you need to build a port to move them to new markets. You can choose to:<br>Use: **3 connecting spaces (can be mangrove or empty)**<br>Earn: **+3 people points** | You use firewood for fuel and mangroves are near your home. You can gather mangroves for firewood if you choose to:<br>Use: **1 mangrove space**<br>Earn: **+1 people point** |
| Your city is expanding and needs new spaces for housing and shops. If you want to build, you can choose to:<br>Use: **2 connecting spaces (can be mangrove or empty)**<br>Earn: **+2 people points** | People would like to be able to drive along the coast. You can build a road if you choose to:<br>Use: **2 connecting spaces (can be mangrove or empty)**<br>Earn: **+2 people points** | You own a farm and want to divert fresh water to irrigate your crops. This diversion can change ocean salinity and harm mangroves. You can choose to:<br>Use: **1 mangrove space**<br>Earn: **+1 people point** |

***Figure 3.6:* *Blue Carbon Game cards*.**

 

16. Read *Blue Carbon Game* and play the game with your team.

## *Blue Carbon Game*

Now you will play a game to learn more about blue carbon, using mangroves as an example. This game is best played with two to five players.

**Setup**

a. Shuffle the *Blue Carbon Game cards* you made from Figure 3.6.
b. Have each player take out a piece of scrap paper or something else to mark on to help keep track of their individual people points.
c. Gather your pieces: You need two sets of 20 small items each. These items could be paper clips, small stones, blocks, or whatever is easily available. One set of these items will be Mangrove Pieces. The other set will be Built Pieces that represent things built by people.
d. Create the game board: You will need a board with 20 spaces. You can draw this on a piece of paper divided into 20 rectangles. You could also use colored tape and a table and divide it into 20 spaces. Make sure the game pieces you just gathered can fit in the spaces.
e. Set up the board: Place 10 Mangrove Pieces on any 10 of the 20 spaces of your game board. These spaces can be next to each other or spread out. Figure 3.7 shows an example.

| | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| X | X | X | X | X |
| X | X | X | X | X |

*Figure 3.7: Example of a game board setup. The X marks represent the Mangrove Pieces.*

Part 3 Task 1

 

**Playing the Game**

f. Your goal is to get as many people points as possible. Each player keeps track of their own people points.

g. There are five years, or rounds. For each year:

- First, go around the circle and have each player take a turn.
- Second, calculate your carbon score.
- Third, read the *Yearly Event* section and follow the directions.
- Finally, reshuffle your *Blue Carbon Game cards* and begin the next round.

**On Your Turn**

a. Pick a *Blue Carbon Game card.*

b. You can choose to follow the directions on the card, or you can choose to do nothing.

c. *Blue Carbon Game card* directions:

- Use: If you choose to use a space, add a Built Piece to that space. If the space is empty, just add the Built Piece. If the space has a Mangrove Piece, replace it with your Built Piece. Keep together the Mangrove Pieces that have been removed during the round, so they can be counted at the end of the year.
- Change: If you choose to change a space, add a Mangrove Piece to that space. If the space is empty, just add the Mangrove Piece. If the space has a Built Piece, replace it with your Mangrove Piece. If you add Mangrove Pieces, do not use the same ones you removed earlier in the round.
- Earn: Add any people points you earned to your piece of scrap paper.

d. Discard your *Blue Carbon Game card* and the next player begins their turn.

**Calculate Your Carbon Score**

e. After each player has had a turn, pick a scorekeeper to calculate the carbon score for the group.

f. After Year 1 (the first round), have the scorekeeper create the *Carbon Scoresheet*. Print out the scoresheet shown in Figure 3.8 or create a similar scoresheet on a piece of paper or a class board. This scoresheet will be used throughout the game.

Part 3 Task 1

 

| Year | Atmospheric Carbon | Carryover Excess Carbon Balance | Carbon Bomb (any mangroves you remove in this year) | Blue Carbon Sink (number of mangrove squares at the end of the year) | Excess Carbon Balance |
|---|---|---|---|---|---|
| 1 | 10 | 0 | | | |
| 2 | 10 | (from Year 1) | | | |
| 3 | 10 | (from Year 2) | | | |
| 4 | 10 | (from Year 3) | | | |
| 5 | 10 | (from Year 4) | | | |

***Figure 3.8:*** ***Carbon Scoresheet*.**

g. At the end of the year, count:
   - The number of Mangrove Pieces removed during the year. Record this number in the *Carbon Bomb* column.
   - The number of Mangrove Pieces you have left on your game board. Record this number in *Blue Carbon Sink* column.

h. Calculate:
   - Add: *Atmospheric Carbon* (always 10) + *Carryover Excess Carbon Balance* (0 for Year 1, then take the number from the previous year) + *Carbon Bomb*
   - Subtract: *Blue Carbon Sink*
   - Overall equation: (Atmospheric Carbon + Carryover Excess Carbon Balance + Carbon Bomb) – Blue Carbon Sink = Excess Carbon Balance

i. Record the number you calculated under *Excess Carbon Balance* for your year. Also write this number in the *Carryover Excess Carbon Balance* column for the following year. If your excess carbon is less than 1, use that negative number in your calculations.

**Yearly Events**

j. Read the *Yearly Event* from Figure 3.8 for the year you just completed, and follow the directions.

| |
|---|
| After Year 1: If your *Excess Carbon Balance* is zero or less, congratulations, you have balanced your carbon. If you have an empty square, create a new mangrove square as your forest expands. |
| After Year 2: A tropical storm hits your area, but mangroves can help protect against storm surge. If you have fewer than 8 mangroves, each player loses 2 people points, or as many as they have if less than 2. |
| After Year 3: Excess carbon in the air leads to rising temperatures, which leads to rising sea levels. If you have more than 5 *Excess Carbon Balance* at the end of this round, remove 2 mangroves after they are harmed by the rising sea level. Record these removed mangroves under *Carbon Bomb* for Year 4. |
| After Year 4: Excess carbon in the air leads to rising temperatures, which leads to more extreme weather. If you have more than 5 *Excess Carbon Balance* at the end of this round, a powerful tropical storm hits your area and damages the mangroves. Remove 2 mangroves and each player loses 2 people points. |
| After Year 5: Excess carbon in the air leads to rising temperatures, which makes people uncomfortable and crops harder to grow. If you have more than 5 *Excess Carbon Balance* at the end of this round, each player loses 3 people points. |

***Figure 3.9: Yearly Events to read after each round.***

k. Continue playing the game until you complete Year 5.
l. Have each player add up all their people points.

After playing, discuss with your team:

a. Who had the most people points? How do you feel about that?
b. Was there anything that concerned you by the end of Year 5?
c. What are some different perspectives (social, environmental, economic, and ethical) different people might have in this community?
d. How do you think this game relates to what is happening with mangroves and other blue carbon sinks?

Part 3 Task 1

 

### ⚠ Emotional Safety Tip

It can be discouraging to think that an Excess Carbon Balance is building up in the game, just like it is in Earth's atmosphere. But this does not need to be so. People can make different choices. You will now play the game again with a different goal, to think about what those different choices might be like.

**Play Again**

Imagine you had started with a different goal: making sure there was no *Excess Carbon Balance*. How do you think you would have played differently?

Go back and play the game again. But this time, instead of trying to get the most people points for you as an individual, try to cooperate with the other players to make sure there is no *Excess Carbon Balance* at the end of each year. Share all the people points as a group instead of keeping track of them for each individual.

### ⚠ Emotional Safety Tip

Discuss your ideas and try to work together. However, even though you are playing cooperatively, some people may make decisions that you disagree with. Show respect for your teammates and their decisions.

Discuss as a team:

a. How did playing cooperatively change the game for you?
b. Did you feel you had to make sacrifices when playing cooperatively? Are you happy with the result of those sacrifices?
c. What lessons do you think you can learn from the differences between the two ways to play?

Reflect on the game:

a. A newly planted mangrove takes many years of growth before it can store the same amount of blue carbon as a mature mangrove. The *Blue Carbon Sink* calculation in this game treats new mangroves and mature mangroves as the same, but this is inaccurate. How would you change the calculations to help people understand that newly planted mangroves can't replace the carbon storage in an older mangrove?

13. Read *At the Smithsonian* and discuss with your team: How can the work of scientists help us anticipate and plan for what could happen in the future?

### *At the Smithsonian*

Blue carbon locations, like mangroves and salt marshes, don't just provide important carbon storage. They also help with water quality, provide habitats for plants and animals, and protect communities against **storm surge**. But what will happen to them as the climate changes? The Smithsonian Environmental Research Center (SERC) is working to find out.

The Global Change Research Wetland at SERC includes a 38-year-long experiment, the world's longest climate change experiment. Over the years many additional experiments have been added to the salt marsh research area, each one building on the one that came before. For example, one experiment adds carbon dioxide to research spaces to understand how the marsh changes in response. Another warms an area to observe changes. Another examines how the rising sea levels associated with climate change might change the marsh system—and there are many more.



 

*Figure 3.10: Aerial photo of the Global Change Research Wetland showing some experimental setups.*

If we want to make sure that this salt marsh ecosystem can keep storing carbon and helping people in other ways, we need to know how to protect it. Scientists have learned a lot about how this important blue carbon ecosystem will respond to global changes. Doing research like this is one way to help people prepare for the impacts of a changing climate.

To watch a video about the Global Change Research Wetland, visit the *Ocean!* StoryMap.

## **Act:** *How can we be a positive part of the system to regulate Earth's air?*

As you have learned, the living things on Earth generally live in a balanced system of the air, the ocean, and the land. Oxygen and carbon cycle between these different elements of the system. However, recently, people have added a lot of carbon to the system by burning fossil fuels. This additional atmospheric carbon dioxide has unbalanced the system. This is changing our global climate.

Additional atmospheric carbon dioxide also means more carbon dioxide is now dissolved into the ocean. You will learn more about the effects of increasing amounts of carbon dioxide in the ocean in Task 2. In this activity you will think about how people acting differently can limit the changes to the existing system.

1. Take out your *Ocean and Air System Diagram* and examine it.
    a. Think about human actions you have learned about, such as emissions from burning fossil fuels or creating carbon bombs when removing mangroves.



 

b. Circle any arrows where you think the actions of people might be unbalancing the system.

2. Read Rebecca's ideas about what is unbalancing the system of ocean and air. If she makes you think of any other places where additional carbon dioxide from people might be changing the system, circle those arrows on your *Ocean and Air System Diagram*.

***Rebecca says . . .***

The oceans have absorbed 25% to 30% of the carbon dioxide that humans have released into the atmosphere. The largest source of this carbon dioxide is the burning of fossil fuels. When $CO_2$ dissolves in seawater, it fundamentally changes the chemistry of that water in a variety of ways, ultimately making it more **acidic**—with broad consequences for marine life.

3. Discuss with your team your ideas about what could restore the balance in the unbalanced places you identified. Here are some ideas:
   a. Changing specific behaviors to use fewer fossil fuels, for example, walking instead of driving or using less energy to heat your home.
   b. Changing the system, for example trying to encourage different types of electricity production or transportation that use energy sources that are not fossil fuels.
   c. Changing the amount of stored carbon, for example helping to protect blue carbon ecosystems.
   d. Changing other things you can think of to restore the balance.
4. Decide as individuals or as a team one thing you want to do to help restore the balance to the atmosphere system.
5. Take a piece of paper or a class board and divide it into four sections. Label the sections "**Social**," "**Environmental**," "**Economic**," and "**Ethical**." Figure 3.11 shows an example.



 

| <u>Social</u> | <u>Environmental</u> |
| --- | --- |
| | |
| <u>Ethical</u> | <u>Economic</u> |
| | |

*Figure 3.11: Example of a chart showing the four perspectives.*

6. Think about your idea to restore balance. What are the possible social, environmental, economic, and ethical effects on your local and global communities?
7. Have each team member write any positive or negative effects they can think of in the section for each perspective.
8. Think about your idea to restore balance. Are there any social, environmental, economic, or ethical concerns?
9. Take out your <u>*Ocean Identity Map*</u> and remind yourself of your *Hopes* and *Concerns* for the ocean.
10. Have each team member list any concerns in the appropriate perspective section.
11. As a team, examine your rebalancing idea and the perspectives you have listed. Are there ways to change your idea to resolve any concerns?
12. Write down your modified idea, or find some other way to remember it. You will need it again at the end of Task 2.



 

# Task 2: How can we prevent ocean acidification?

As carbon dioxide increases in the atmosphere, it reacts with ocean water. This changes the ocean's chemistry. In this task you will ***discover*** more about how this process works. Then you will investigate to ***understand*** how changes to the chemistry of the ocean might affect the living things of the ocean. Finally, you will decide how to ***act*** to share what you have learned and **collaborate** with others to address problems related to these changes.



***Discover:*** *How does increasing carbon dioxide lead to changes in ocean chemistry?*

You learned in Task 1 about how Earth's carbon cycle slowly moves carbon between the land, the ocean, the air, and living things. This balanced cycle has been working for millions of years and is the source of most movement of carbon around the planet. However, even relatively small changes to this system over time can have big consequences. In Figure 3.4 you may have noticed that over the last 150 years, as humans used more and more fossil fuels, the amount of carbon dioxide in the atmosphere has increased more and more rapidly. There is now 50% more carbon dioxide in the air than there was 150 years ago. In this investigation you will gather information about when you and your community are using fossil fuels and how increased carbon dioxide in the atmosphere is changing the ocean's chemistry.

1. Take out your *Ocean and Air System Diagram*.
2. Draw a boundary around the elements in your system diagram to show the current atmosphere and ocean.
3. Add *Additions* that show anything in your local community that might be adding additional carbon dioxide to the atmosphere. Figure 1.7 shows an example, if you need help. Be sure to consider:
   a. Transportation in your community that may use fossil fuels (such as cars, trucks, and buses that run on gasoline or petrol)
   b. Buildings or spaces in your community that use fossil fuels to make them comfortable and usable (such as for lighting or heating or cooling air)
   c. Cooking that may use fossil fuels

 

    d. Manufacturing items may use energy from fossil fuels
    e. If you want to learn more about fossil fuel use and energy, you can visit the Smithsonian Science for Global Goals *Energy!* guide.

4. Discuss with your team: What are the main things in your community you think may be adding carbon dioxide to the atmosphere? If you have time, you can visit the *Ocean!* Storymap for further resources on how to find sources of carbon dioxide from your community.
5. Examine your *Ocean and Air System Diagram*.
    a. How would you guess the increasing concentration of carbon dioxide in the atmosphere might affect the ocean?
    b. How might the emissions from a community far away from the ocean still affect the ocean?
6. Read *Investigating Ocean pH Change* and follow the instructions.

Part 3 Task 2

## *Investigating Ocean pH Change*

The water of the ocean is Earth's biggest carbon sink. When ocean water is next to the air, it absorbs carbon dioxide from the air. The movement of water, such as wave action and sea spray, also mixes air into the water. The more carbon dioxide in the air, the more the water of the ocean absorbs. Scientists estimate that ocean water has absorbed about 31% of the atmospheric carbon emissions from people. But absorbing this extra carbon has an impact on the ocean.

You will model this now and try to find out whether this reaction makes the ocean water more acidic or more **basic**. You can measure how acidic or basic a substance using a pH scale. A pH scale ranges from 0 to 14. Measurements on the lower end of the scale are strong acids. Measurements on the higher end of the scale are strong bases.

a. Take four clear containers—plastic or glass cups work well.
b. Label your containers A, B, C, and D.
c. Decide whether you will use a pH indicator or another method of measuring pH, and use the instructions for either a pH indicator or another method.

 

## Using a pH Indicator

a. Find a pH indicator. You can use indicators made from plants such as red cabbage. To use red cabbage or other similar plants to make a pH indicator, pour boiling water into a container containing several leaves or fruits of the plant. Figure 3.12 shows an example. After about 5 minutes, strain out the leaves or fruit. The liquid should be dark blue. The *Ocean!* StoryMap has more information if you need it.

*Figure 3.12: Setup for making a red cabbage pH indicator.*

b. Add around half a cupful of the indicator liquid to each cup.
c. Do not add anything more to Cup A. This will be your control cup.
d. To Cup B add an acid, such as lemon juice or vinegar. This will be your acid cup.
e. To Cup C add a base, such as baking soda. This will be your base cup. Figure 3.13 shows an example of these cups.

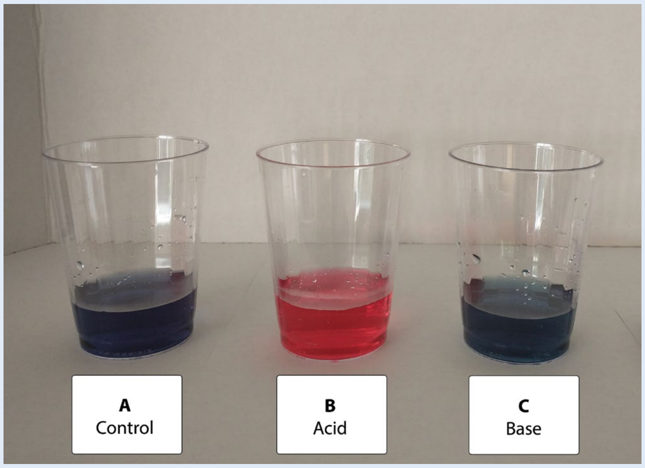


*Figure 3.13: Example of Cup A (control), Cup B (acid) and Cup C (base) using the red cabbage indicator.*



 

f. Add carbon dioxide to Cup D. This will be your experiment cup. You can do this in two ways. Try one or both.

   a. Option 1: Put a straw in Cup D and blow out into the straw for about 30 seconds. Remember, you breathe out carbon dioxide, so you are adding carbon dioxide to the water. Figure 3.14 shows an example.

*Figure 3.14: Adding carbon dioxide to Cup D using option 1.*

### ⚠ Physical Safety Tip

Only blow out when using the straw. The red cabbage pH indicator will not harm you, but tasting it will not be pleasant. Do not share straws with others.

### ⚠ Emotional Safety Tip

Even though you are breathing out carbon dioxide and changing the chemistry of the water, this is just a model. The carbon dioxide you breathe out as a person is not the reason carbon dioxide in the atmosphere is increasing. You breathing in and out is a natural part of the carbon cycle. Other human behaviors, such as fossil fuel use, are the reason atmospheric carbon dioxide is increasing.



 

b. Option 2: Use aluminum or tin foil and create a small, cupped container that is hooked over the edge of Cup D. Add baking soda to this small container. Place a piece of plastic wrap or cling film partially over the cup. Figure 3.15 shows an example. Add a spoonful or two of vinegar just to the small container and immediately cover the remainder of the cup with the plastic wrap. Baking soda and vinegar react to create carbon dioxide. You have now trapped carbon dioxide in the air next to your pH indicator.

*Figure 3.15: Adding carbon dioxide to Cup D using option 2.*

g. Observe Cup D closely. It started out the same as Cup A. Is it now closer to Cup B (acid) or Cup C (base)?
h. Do you think carbon dioxide made the water in the indicator liquid more acidic or more basic?

### Using a pH Strip or Meter

a. If you prefer to not use an indicator, you could use a pH meter or strips to measure pH.
b. Add around half a cupful of water to all cups.
c. Follow steps c through f under *pH Indicator*.
d. Test the pH of Cups A, B, and C.
e. Note down the results of your measurements. All cups started the same as Cup A (water). Cup B should be more acidic (less than pH 7) and Cup C should be more basic (more than pH 7).

Part 3 Task 2

 

f. Add carbon dioxide to Cup D using option 1 or 2.
g. Test Cup D. Is it more or less than pH 7?
h. Do you think carbon dioxide made the water more acidic or more basic?

Discuss with your group or team:

Do you think the pH of the ocean is changing as carbon dioxide in the atmosphere increases?

The pH scale is **logarithmic**. That means that a change between 7 and 6 means a substance is 10 times more acidic. So even small changes in pH can have big impacts.

7. Read Rebecca's thoughts about changes in pH. How does it make you feel about any change of the pH of the ocean?

***Rebecca says . . .***

The open ocean used to be a pH of 8.2. Now it is 8.1. Because it is a logarithmic scale, that is a 30% increase in acidity. If you had a 30% increase in acidity in the pH of your blood, it would have serious consequences for your body. It is a huge shift.

8. Examine the graph in Figure 3.16. It shows the change in pH of the ocean since 1988. Discuss with your team:
   a. Notice: What do you notice about the graph?
   b. Think: Compare Figure 3.16 with the atmospheric data graph from Figure 3.4. The Figure 3.16 graph starts in 1988, but the graph in Figure 3.4 starts in 1750. Rebecca told you that the pH of the open ocean used to be 8.20. But in Figure 3.16 the first pH measured is around 8.11. Thinking about the rise of atmospheric carbon dioxide shown in Figure 3.4 and how that relates to lowered pH, what do you think happened to the pH of the ocean between 1750 and 1988?
   c. Wonder: What do you wonder about how this change affects the ocean?



 

**Ocean Acidification: Mean Seawater pH**

Mean seawater pH is shown based on in-situ measurements of pH from the Aloha station in Hawaii

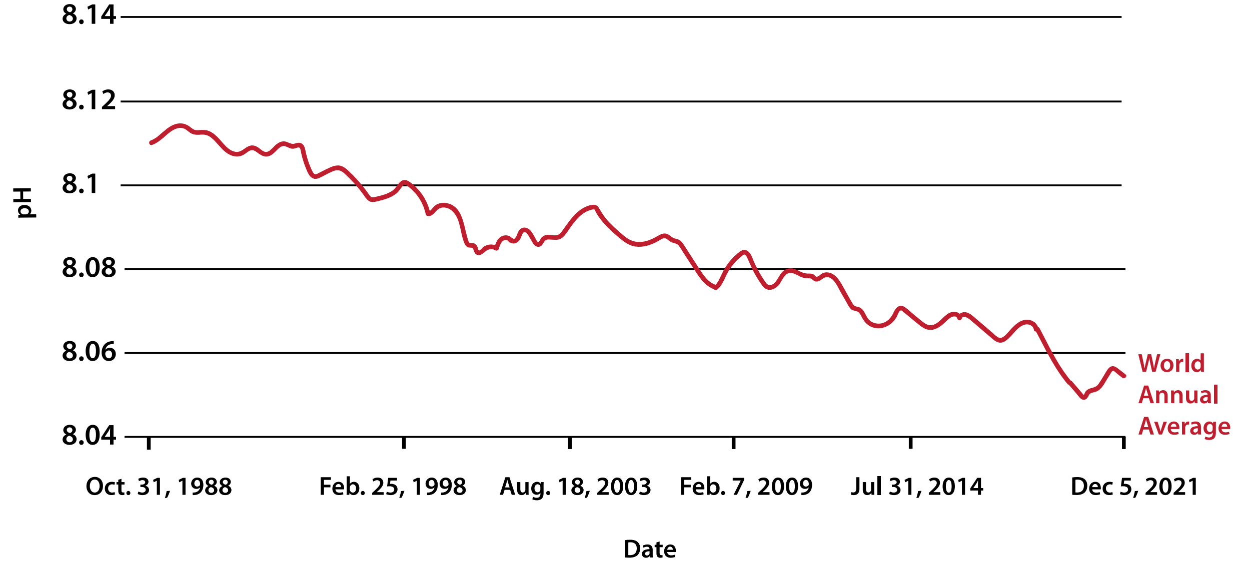


*Figure 3.16: Changes in seawater pH between 1988 and 2021[2].*

## ***Understand:*** *What does an acidifying ocean mean for ocean ecosystems?*

Increasing emissions are adding carbon dioxide to Earth's atmosphere. When the amount of carbon dioxide increases in the air, it also increases in the water. The increasing amount of carbon dioxide in the water lowers the pH of the ocean and makes it more acidic. This **ocean acidification** is changing the environment for the ocean's organisms. How do you think this might affect the living things in the ocean? In this activity you will investigate to find out more.

1. Take a deep breath, then another.
2. Think quietly to yourself: Have you ever been in a situation where the air you were breathing changed in some way? For example, maybe you were at a high elevation so there was less oxygen in the air, or maybe there was smoke or something that made you cough in the air. How did changes to the air affect you and your body?
3. Compare this with the organisms of the ocean. Think quietly to yourself:
    a. How is our experience with the air around us similar to marine organisms' experience with ocean water?

 

b. How might changes in the chemistry of the water surrounding marine organisms affect them?

4. Discuss with your team any ideas you have about ways a more acidic ocean might affect the living things of the ocean. Make a note of your ideas.
5. Read *Acidification Investigation* and use it to explore how ocean acidification might affect organisms with hard shells.

## *Acidification Investigation*

a. In a small group or team, list any ocean organisms you can think of that have hard shells.
b. If you can, gather five shells from the same ocean organism to use in this experiment. For example, you could use clam, oyster, or mussel shells. If these types of shells are unavailable, gather five (empty) eggshells to use. Any type of eggshell is fine. Eggshells are made of a material called **calcium carbonate**, just like shells in the ocean. If you use eggshells, try to remove the membrane from the inside of the shell.
c. Take out five clear containers, such as the ones you used to model the ocean pH change.
d. If you have a scale, weigh each shell.
e. Place one shell in each cup, noting the weight, if you can.
f. Mark the cups 0%, 25%, 50%, 75%, and 100%. Figure 3.17 shows an example.

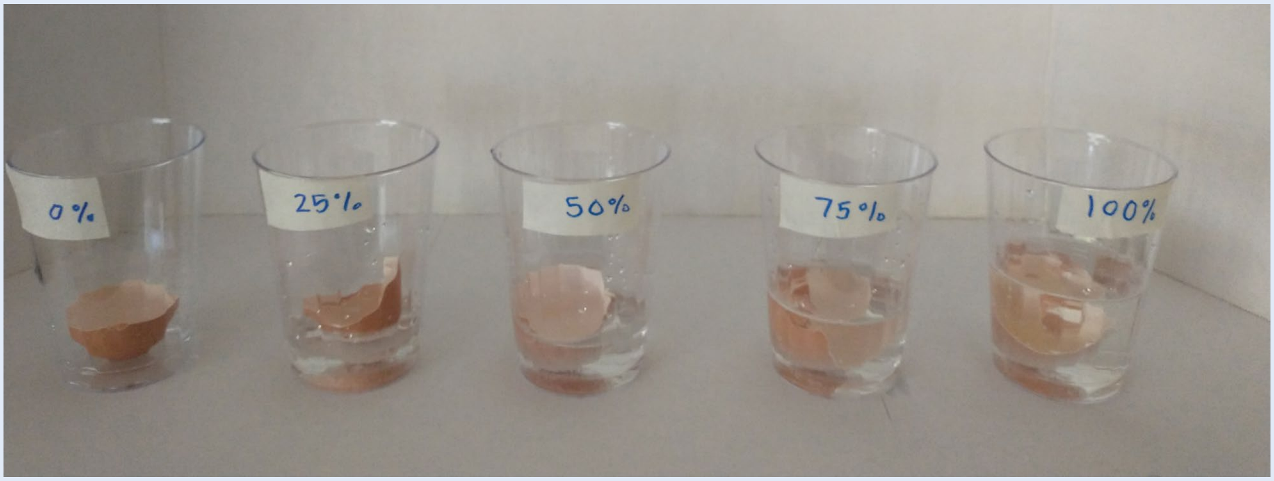


*Figure 3.17: The Acidification Investigation setup with only acid added to each cup.*



 

g. Fill the 0% cup with water. (For each cup make sure there is enough liquid to completely submerge the shell.)
h. Fill the 25% cup with one quarter acid, such as vinegar or lemon juice, and then fill the remainder with water.
i. Fill the 50% cup half full of acid and half full of water.
j. Fill the 75% cup three-quarters full of acid and one-quarter full of water.
k. Fill the 100% cup with acid.
l. Leave the cups undisturbed for at least 24 hours.
m. Return to the cups after 24 hours and remove the shells.
n. Examine the shells and record anything you notice about differences between the shells in the different cups.
o. If you weighed the shells, wait until they are dry and weigh them again. Compare these weights to the original weights.

Discuss with your group or team:

a. What did you notice about the results from the different solutions?
b. What do you think is causing those results?
c. How do you think an acidifying ocean might affect marine organisms with shells?

Ocean acidification can make it more difficult for shell-building organisms to access the **carbonate ions** they need to build their calcium carbonate shells. This makes it harder for them to grow. Some common organisms with calcium carbonate shells include **shellfish** such as oysters and crabs, corals, sea urchins, and some types of plankton. At higher levels of acidification, shells can start to actually dissolve—as you may have noticed in this acidification investigation.

6. Read Rebecca's thoughts about how ocean acidification can affect living things. Are there things that concern you that you think should be added to your *Ocean Identity Map Concerns* circle? If so, add them now.



 

***Rebecca says. . .***

How bad is ocean acidification? What are the impacts? The impacts of ocean acidification are widespread and vary from animal to animal and system to system. For corals, an organism I study, ocean acidification impacts growth (**calcification**) and reproduction. This is a particular problem because when a species or a population gets harmed or damaged, for example during a **coral bleaching** event, reproduction and growth are two of the most important recovery processes for rebuilding the population.

7. Return to your *Ocean and Air System Diagram* and add any additional elements or relationships you can think of.

### ***Act:*** *How can we stop the ocean from acidifying?*

Most ocean organisms thrive in an ocean pH of around 8.2. The average pH of the ocean is now under 8.1. By 2100, scientists estimate the pH of the ocean will be between 8.05 and 7.75, depending on the amount of carbon dioxide emissions between now and then. How can we be a part of efforts to limit ocean acidification?

1. Take out a piece of paper or use a class board and divide it into three sections.
2. With your team or a partner, discuss the impact of ocean acidification from the four perspectives you have learned about. Write your ideas in the middle section of your paper or board. For example:
    a. Social perspective: Are there parts of the system that link the ocean or air to human cultures, food, or health?
    b. Environmental perspective: Are there parts of the system that link different parts of the environment, such as between different organisms in a marine ecosystem?

 

c. Economic perspective: Are there parts of the system that people depend on to make money?

d. Ethical perspective: Are there parts of the system that may be linked in a way that feels unfair?

3. Read Rebecca's thoughts to help you consider different perspectives.

***Rebecca says . . .***

Ocean acidification can affect communities in a lot of different ways. For example, some shellfish industries, including mussels, oysters, and clams, are beginning to be impacted by ocean acidification. In many cases, early life stages of these shellfish are very vulnerable to the stress of ocean acidification. For example, there have been failures of oyster hatcheries because of acidified waters that cause larval cultures to crash and die. This can have huge economic consequences for surrounding communities, including fisheries and restaurant industries.

Corals, an organism that I study, are also highly impacted by ocean acidification. Corals are the building blocks of coral reef ecosystems, which support about 25% of the biodiversity in the oceans. Coral reefs support the fish that are the primary protein source for millions of people around the world. And coral reefs protect human communities, mitigating around 97% of wave energy. In areas with cyclones or hurricanes, coral reefs act like a storm wall for protecting coastal infrastructure and livelihoods.

4. Think with your team: What are some possible concerns of an acidifying ocean? Add these to your *Concerns* circle on your *Ocean Identity Map*. What do you hope will happen to stop those concerns? Add those ideas to your *Hopes* circle.

5. Think quietly to yourself.

   a. Before working on these tasks, how well did you understand ocean acidification and the threat it poses?

   b. How do you feel about these changes to the ocean?

 

### ⚠ Emotional Safety Tip

It can be difficult to think about changes to the ocean and ocean acidification. It is okay to feel sad, angry, frustrated, or upset. Ocean acidification is not your fault, but you can become part of efforts to make things better.

6. Discuss with your team: Do you think people in your community understand ocean acidification and their connection to it?
7. In the first section of your paper or board, write or draw your ideas about the sources or causes of ocean acidification. What is putting excess carbon dioxide in the air? You can use your *Ocean and Air System Diagram* to help you remember.
8. In the middle section, you should already have your ideas about how ocean acidification can affect marine organisms, people in your community, and people from around the world from step 2.
9. In the third section, write or draw your ideas about rebalancing the system from Task 1.
10. Add to the third section any other actions you or others in your community could take to stop ocean acidification. Try to be as specific as possible about actions you could take that are related to the following general categories:
    a. Communicate with others to share information about the process and effects of ocean acidification.
    b. Change daily behaviors to use fewer fossil fuels.
    c. Encourage local businesses or local government to use fewer fossil fuels.
    d. Join with existing groups to help increase the message about the threats of ocean acidification and its links to carbon dioxide emissions.
    e. Other ideas that might be important to creating change.
11. If you are having trouble coming up with ideas for actions, you can read Rebecca's thoughts to help you.



 

***Rebecca says . . .***

There are different ways to think about solutions to ocean acidification. The best thing is to limit ocean acidification by cutting carbon emissions. That helps to actually solve the problem. But you also could think about ways to protect ecosystems as ocean acidification is happening at a local or regional level. For example, you could try to eliminate other sources of stress, such as heat or pollution or over-fishing. If you can remove all those other problems, it relieves the total amount of stress on the system.

What I have been researching recently is the possibility of buffering seawater by adding chemicals to reverse ocean acidification. This is a very new idea and we still are in the early stages of understanding whether it might work. I actually led the only field study that's assessed this on a coral reef. It did help the coral, but we are just beginning to learn about this, so we have a long way to go.



12. With your team, examine the potential actions you all listed.
13. Have each team member draw a star next to the action that seems like it would be the most useful for your community right now.
14. Have each team member make a check mark next to the action that seems like it would be the easiest thing for you to do right now.
15. As a team, examine your team list of actions and the stars and checks. Discuss your ideas until you find **consensus** over which action to take.

**⚠ Emotional Safety Tip**

Sometimes it is overwhelming to think about all the things that could be done to help make a problem better. You may feel guilty for not doing more. As an action researcher and action-taker, it is important to understand that you do not have to and could not solve this problem alone. There are many people around the world working to make things better. When you are thinking about taking action, sometimes you will only be able to do something small. Sometimes you can do something bigger. That is okay. Do your best and remember that any positive change helps make things better. Bit by bit, people are working together toward global progress.

 

16. With your teammates, make a plan to take action. Create a list with the steps you need to take to carry out your action. Be sure to consider:
    a. If you need to share information, where, when, and with whom will you share it?
    b. If you need to do something, what and where do you need to do it?
    c. If someone outside your team needs to be involved, how will you communicate with them?
    d. If you need to get any materials, when and where will they be gathered?
17. Think about how each team member will help. Put their names with the steps they would like to help with.
18. Title a sheet of paper "Action Plan" and record the following:
    a. The steps your team would like to take
    b. The order of those steps
    c. Who will help with each step (it might be more than one person)
    d. When and where you will take these steps
    e. Partners or others you will involve
    f. How you will communicate your action plan to the community
19. Think about what you will do if your plan doesn't work or you run into another problem. For example, what will you do if an adult in your community says you need permission to do something? Record these ideas as part of your action plan.
20. Remember to create an **inclusive** action plan. Being inclusive means everyone on your team can participate in some way. You may need to make changes to the plan so that everyone feels safe, comfortable, and able to help. Those changes are okay! They are part of being a good teammate and taking sustainable action.
21. Put your plan into action.
22. Afterward, reflect on your action:
    a. What seemed to go well?
    b. What was hard?
    c. Were you able to make the changes you thought you would be able to make?
    d. Will you keep going with your plan or are there things you would do differently in the future?
23. Save your *Ocean and Air System Diagram*. You will need it in Part 7.



 

# Congratulations!

# You have finished Part 3.

***Find out More!***

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.



 

# End Notes


1. Lindsey, Rebecca. "Climate Change: Atmospheric Carbon Dioxide." NOAA Climate.gov. Accessed December 7, 2023. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.
2. Our World in Data, and Max Roser. "Conserve and Sustainably Use the Oceans, Seas and Marine Resources." Our World in Data, July 21, 2023. https://ourworldindata.org/sdgs/life-below-water.




 

# Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

**Acidic:** Having a pH below 7

**Atmosphere:** The mixture of gases that surround Earth

**Basic:** Having a pH above 7

**Blue Carbon:** Natural carbon storage that happens in coastal wetlands such as mangroves, seagrass beds, and salt marshes

**Calcification:** The process of depositing calcium carbonate to grow shells or other structures, such as coral reefs

**Calcium carbonate:** A naturally occurring solid, often found in forms such as chalk or limestone, and used by some organisms to build shells or coral structures

**Carbon bomb:** A large amount of previously stored carbon released into the atmosphere because an ecosystem is disturbed or eliminated

**Carbon cycle:** The cyclical movement of carbon between Earth's organisms, the ocean, the land, and the air

**Carbon sinks**: Environments or living things that store carbon

**Carbon storage:** When carbon is buried and isolated from the air



 

**Carbonate ions:** Molecules that are essential for marine organisms to use in building shells

**Collaborate:** To work together towards a common goal

**Coral Bleaching:** When the water around coral gets too hot, algae is expelled and the coral turns white or light

**Consensus:** A balanced decision that works for everyone in the group

**Cyanobacteria**: Microscopic marine organisms also known as blue-green algae

**Decompose:** Breaking down living things so their matter can cycle again through the ecosystem

**Economic:** About money, income, or the use of wealth

**Environmental:** About the natural world

**Emissions:** Greenhouse gases released into the atmosphere from burning fossil fuels

**Ethical:** The fairness of something

**Fossil fuels:** Types of carbon-based fuels, such as petroleum (oil), natural gas, and coal

**Greenhouse gases:** Gases such as carbon dioxide and methane that trap heat and cause the atmosphere to get warmer



 

**Inclusive:** Making sure no one is left out

**Logarithmic:** A scale where the distance between two whole numbers, such as 7 and 8, is a ten-fold increase or decrease; similarly, the distance between 7 and 9 would be a hundred-fold increase or decrease

**Ocean acidification:** The process by which increasing levels of carbon dioxide in the air react with the ocean to lower the pH of the ocean water

**Photosynthesis:** The process plants use to make food, taking in sunlight and carbon dioxide and releasing oxygen

**Phytoplankton:** Photosynthetic organisms living in the upper part of the ocean that are moved by ocean water; also called microalgae

**Plankton:** Tiny organisms that drift in the ocean and are an important part of ocean food webs

**Sediments:** Materials that settle on the bottom of a body of water

**Shellfish:** A mollusk (such as an oyster or mussel) or crustacean (such as a crab or shrimp) that lives in water

**Social:** Relating to the interaction of people in a community

**Storm surge:** A rise in the level of the ocean in an area where there is a storm

 