Smithsonian | SCIENCE *for Global Goals*

OCEAN!

How can we create a sustainable future for the ocean?

SUSTAINABLE DEVELOPMENT GOALS

developed by
Smithsonian
Science Education Center

in collaboration with
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the interacademy partnership

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Ocean!

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Community Research Guide

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Smithsonian Science Education Center

The Smithsonian Science Education Center (SSEC) is operated by the Smithsonian Institution to improve the teaching and learning of science for students in the United States and throughout the world. The SSEC disseminates information about exemplary teaching resources, develops curriculum materials, supports the professional growth of science teachers and school leaders, and conducts outreach programs of leadership development and technical assistance to help school districts implement inquiry-centered science programs. Its mission is to transform the teaching and learning of science in a world of unprecedented scientific and technological change.

Smithsonian Institution

The Smithsonian Institution was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge . . ." This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

Smithsonian Science for Global Goals (SSfGG) is a freely available curriculum developed by the Smithsonian Science Education Center (SSEC) in collaboration with the InterAcademy Partnership. It uses the United Nations Sustainable Development Goals (SDGs) as a framework to focus on sustainable actions that are student-defined and implemented.

Attempting to empower the next generation of decision-makers capable of making the right choices about the complex socio-scientific issues facing human society, SSfGG blends together previous practices in Inquiry-Based Science Education (IBSE), Social Studies Education (SSE), Global Citizenship Education (GCE), Social Emotional Learning (SEL), and Education for Sustainable Development (ESD).

Thank You for Your Assistance

the interacademy partnership

Thank You for Your Support

This project was supported by the Gordon and Betty Moore Fund through Grant #11240 to the Smithsonian Science Education Center.

Acknowledgments

How can we create a sustainable future for the ocean?

Part 1: Ocean Introduction

- Task 1: What are our connections to the ocean?
- Task 2: What are ocean systems and why are they important?

Part 2: Ocean and Water

- Task 1: How does water move around our planet?
- Task 2: How do circulating water pollutants affect our planet?

Part 3: Ocean and Air

- Task 1: How do ocean systems help regulate Earth's air?
- Task 2: How can we prevent ocean acidification?

Part 4: Ocean and Heat

- Task 1: How does the ocean help regulate Earth's temperature?
- Task 2: How will a warming ocean affect people and the planet?

Part 5: Ocean and Food

- Task 1: How are the organisms of the ocean linked in a system?
- Task 2: How can people be a sustainable part of ocean food webs?

Part 6: Ocean and Coasts	• Task 1: What are the conflicts over coastal spaces and how could they be resolved?
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Part 7: Taking Action	• Task 1: How are different ocean systems interconnected?
	• Task 2: How will we contribute to a healthy ocean?

Smithsonian
Science Education Center

Dear Parents, Caregivers, and Educators,

As a global community we face many challenges. At times, these worldwide problems can seem overwhelming. We may ask ourselves questions about how to understand these complex problems and whether there's anything we can do to make them better. This community response guide encourages young people to discover, understand, and act on the answers to these questions.

In the years leading up to 2015, people around the world worked together to share their ideas about how our world should be. These ideas became a list of goals, the United Nations Sustainable Development Goals. The goals represent a plan for a sustainable world: a world where peaceful societies collaborate; a world where we live in balance with the environment of our planet; a world in which our economies fulfill our needs; a world that is fair to all.

As youth around the globe engage with the activities in this guide, they will gain an understanding of the science that underlies the Sustainable Development Goals. They will be able to share their knowledge with their community, create tangible ways to help their community make informed decisions, and understand the best places to find additional information on these topics.

Throughout the guide, young people may find themselves asking many questions about fair treatment of people and communities. You do not need to have the answers to any of these questions. The most important thing you can offer young people is the opportunity to question, investigate, think critically and systemically, synthesize, and act. Ask the young people around you how they are feeling and what they are thinking about as they learn this content.

I am immensely grateful to the experts who helped to develop this guide—the InterAcademy Partnership, a collaboration of 140 national academies of sciences, engineering, and medicine; our colleagues across the Smithsonian Institution; and the external subject matter experts who contributed to this guide—for their perspectives and technical support in ensuring the science in this guide is accurate. I also want to say a special thank you to the developer of this guide, Heidi Gibson, for her thoughtful contributions to the *Smithsonian Science for Global Goals* project.

Working together—scientists, researchers, parents, caregivers, educators, youth—we can make a better world for all. This guide is a step toward that grand collaboration.

Thank you for partnering with us to inspire our youth to build a better world.

Best,

Carol L. O'Donnell

Dr. Carol O'Donnell, Director
Smithsonian Science Education Center

About this Community Research Guide

The goal of this guide is to prepare young people to take considered action on pressing global issues. Considered action means young people learn about a problem, connect it to the larger system, consider all the complexities of the problem, decide for themselves the best way to address it, and then execute a solution. Through this process young people are prepared not only to take considered action on a specific issue, but to build the skills needed to take action on all issues that affect them and their communities.

Figure 1: Sustainability Mindsets.

Learners use scientific and socio-scientific investigations to understand their local communities, scientific principles, and innovation possibilities. They then have a chance to immediately apply this information to make decisions that are informed by the results of their investigations. Along the way, young people are prompted to reflect, investigate, think critically, analyze, and build consensus. Engaging in these activities builds important skills of empowerment and agency, open-mindedness and reflection, equity and justice, and global-local interconnection. These sustainability mindsets prepare young people to take an active role in shaping the future of their communities and their world.

A Framework to Discover, Understand, and Act

Throughout the guide, young people are prompted to Discover, Understand, and Act. The three parts of their learning journey are described here.

Discover

Young people already have a lot of information and opinions about the world around them. In this guide, they are prompted to use that knowledge as an entry point. They will discover what they already know and what questions they might have. They are encouraged to consider different perspectives and priorities. This both empowers young people and provides an immediate relevance and context for their investigations.

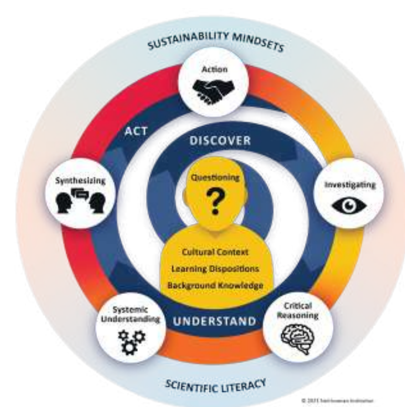

Figure 2: Global Goals Action Progression.

Understand

Gathering new information is a primary goal of science. Using a wide variety of methods to do so helps young people understand the problems related to sustainable communities. They need to understand the problems both abstractly and within the context of their local community. Designing and conducting real-world investigations and interpreting results encourages young people to think like scientists.

Act

Finally, young people apply both their existing knowledge and their newly gathered information. First, they consider personal changes they could make to help make their communities more sustainable. Then, as a team, young people find consensus on what they *could* do, what they *should* do, and what they *will* do. Teams then take action and reflect on the consequences, both intended and unintended.

Pedagogy Shift

This guide may feel like a big shift from the standard method of teaching. The guide is:

Led by Young People

To make progress toward a better world, we need the ideas, enthusiasm, and energy of every young person. We need them to help design and build the world in which they want to live. This means throughout the guide young people make authentic decisions about what and how they will learn. Their goal is to understand issues in their own community and take sustainable actions to make their community and their world better.

Driven by Data Collected by Young People

In this guide, the young people you teach will become action researchers. They will gather information about what sustainable communities mean in their own local spaces. This includes scientific investigations and experiments to understand the problems better, and also using social science methods to understand their community better. Using science and social science helps young people arrive at a sustainable solution.

Focused on Action

The goal of the guide is to help young people not just learn but also do. Throughout the guide young people will conduct investigations and then use that knowledge to make decisions about the actions that would be best for their community. They will then put those decisions into practice and see the results of their actions.

Customized for Local Communities

Each community is unique. While the world has global problems, the solutions must work locally. Young people already have tremendous knowledge about their local community. This guide prompts them to use that knowledge and find out new information to figure out solutions that are sustainable in *their* community.

Structure of this Community Research Guide

Parts

This guide is made up of seven parts. Each part works with the others to help learners understand how to help their community thrive and to put that knowledge to work by taking action.

However, we recognize that time is a limiting factor in many learning spaces. Therefore, the guide is designed flexibly so it can be shortened, if necessary. The learners are guided to do this shortening work themselves at the end of Part 1. The guide prompts learners to discuss with their teacher how much time is available and then make decisions about the best way to use that time.

Tasks

Within each part there are two tasks. Each task helps learners examine a different aspect of the topic they are exploring. Within each task, there are three activities, which correspond to the Discover, Understand, Act framework. Discover activities focus on existing learner knowledge. Understand activities focus on gathering new information. Act activities focus on analyzing and applying that new information to make decisions. Tasks also include perspectives and stories from experts around the globe, so students can connect with the work of real-world scientists.

Using this Guide

Roles

The Learner's Role

Learners are the decision-makers of the guide. They will decide what information they need and what the information they gather means. Then learners use that information to decide and implement actions.

The Teacher's Role

This guide may be challenging for learners, since they may be unfamiliar with their role. Learners may need assistance in deciding what to do. Support and help them, but do not decide for them. Be patient. There are no right answers to the big questions posed by this guide.

Adapting the Guide for Your Context

Different Ages

This guide is designed to be used with young people between the ages of 8 and 17. This large range is deliberate to give access to these ideas to as many young people as possible. If you teach learners who are on the younger end of the age range you may need to support them a little more. For example, you might need to:

- Explain more complex words or topics
- Promote listening and tolerance in group discussions
- Support group decision-making
- Help them plan investigations in their community or accompany the teams on their investigations
- Help learners think through the feasibility of the action they plan
- Present alternate ways of capturing ideas; for example, if the guide suggests learners write, but that is too difficult or is inappropriate for your learners, they can always draw, act out, or just talk about their ideas

If you teach learners who are on the older end of the age range, the language of the guide might seem a little simple. However, older learners who can understand more complex ideas will be able to develop a more nuanced view of the problem and come up with more extensive solutions.

All young people should be able to engage with the guide in a way that is developmentally appropriate for them.

Different Resources

We have assumed you have very basic classroom resources, such as a class board (blackboard or whiteboard), paper, and pens or pencils. If it is not possible to capture learner writing, you can always have learners act out or discuss their ideas. If you do not have the capacity to print out a Community Research Guide for each learner, you or learner leaders can read the guide out loud from a single print or digital copy.

Accessibility

This guide is designed to be widely accessible. The language, tone, and format attempt to be as inclusive as possible to reach learners with a wide variety of learning styles. However, learners with specific needs may need teacher support. As mentioned earlier, the guide activities can always be adapted to fit learner abilities, either by you or by the students themselves.

Different Rules

Each place is different and may have different rules to protect young people and privacy.

Extensions

For each part and many tasks there are additional activities, videos, and resources available digitally. They can all be found at the *Ocean!* StoryMap at https://bit.ly/OCEAN2030.

Teams

Much of the research, decision-making, and action is designed to be done in teams. These teams can range in size from a group of two or three learners to the whole class. As a teacher, this is something to consider before beginning the Community Research Guide.

If you have motivated and responsible learners who need minimal teacher support, you may want to break your class into small teams. Smaller teams will allow individual learners to share their opinions and have more of an impact on team decision-making. With smaller teams, the experience can be more customized to the interests of the individual learner because there are fewer interests represented.

If you have learners who need more support, you may need to keep the class together in one team or have one team for each adult in the class. If you have only one team per adult, an adult can help support learners directly while they are engaging in activities such as conducting investigations and making decisions. However, because the team is larger, individual learners will have less of a voice in decision-making and less impact on group actions.

Alternately, if you have a group of learners with mixed abilities, you can design groups that bring together learners with different strengths. These types of groups can help learners support one another rather than immediately turning to an adult for support.

If you are uncertain whether a small or large group is most appropriate for your learners, you may want to wait and observe them during Task 1. In Task 1 in the Understand activity, learners break into groups and conduct investigations. If learners are able to complete this task independently with fairly limited teacher support, they would probably be successful in a small group. If learners need a great deal of help to complete this activity, you may want to structure group size so they can have more focused adult support throughout the Community Research Guide.

Getting Started

We recommend you give the young people you work with the Student Letter to read. You may also find it useful to read through each part of the Community Research Guide in its entirety before beginning that part. We suggest you encourage your learners to be excited about this new learning adventure. Be prepared to be enthusiastic about their ideas.

Student Letter

Dear Student,

This is the last time you will be called a student in this Community Research Guide. Instead, you will take on a new role as an action researcher. Action researchers are interested in figuring out what to do to make their communities better. They use scientific investigations to help understand the natural world around them. They use social science investigations to help understand the people, cultures, and history of their communities. Then they use the information they gather to help solve problems in their own communities. This guide will help you learn more about this process. The most important thing to know is that you will control your own research and make your own decisions.

Think back to a time when you solved a problem. You first needed to know what you wanted—your goal. Then you needed to figure out what you had to do to achieve your goal. This guide is similar. You will think about goals you have for your local community, then figure out what you need to take action to help reach those goals.

You and your classmates will work as a team to think about information you already have about the place where you live. Then you will investigate your local community and how things work. Finally, your team will decide how to make things better. Together, you will put your decision into action. Sometimes making decisions about what to do is difficult. Don't worry, this guide will give you lots of support.

How to Use this Guide

This guide is designed to help you explore and think about problems in your community. The guide is here to help you. That means you can always change it.

Adapting the Guide

You will notice that in this guide there are often suggestions about different ways of sharing your ideas or doing investigations. This is because different people think and work best in different ways. For example, some people like to draw, some people like to talk out loud, and some people prefer to write to express their ideas. This guide has suggestions, but you can always change the method suggested. You can share your ideas using discussions, acting, signing, telling stories, recording your voice, writing by hand, typing on a computer, drawing, or another way you choose. Think about the way you and your team learn best together. Including everyone on the team is important.

Safety Tips

This guide asks you to do and think about things that may seem unfamiliar. You will notice physical and emotional safety tips in the guide. These will help you stay safe and supported during the activities. Make sure you follow your teacher's directions about staying safe.

Guide Structure

There are seven parts in this guide. Each part has two tasks. Each task has three activities. The activities are called ***Discover***, ***Understand***, and ***Act***. In the ***Discover*** activities you will focus on thinking about information you and your team already know. In the ***Understand*** activities you will investigate to find out new information. In the ***Act*** activities you will put your existing and new knowledge into action by applying it and making decisions. Words that may be unfamiliar will be in **bold** the first time they are used. Then at the end of each part a glossary lists the definitions of these words.

Investigations

You are the one doing the research in this guide. This means often you will develop your own questions and determine the best way to answer them. Developing and answering questions is how scientists find out new information about the world around them. As an action researcher, you need to think like a scientist to discover what you need to know, investigate to find out more information, and think about the meaning of what you found out.

Keeping Organized

In this guide you will have some papers you will need to keep so you can look at them later. You may want to have a folder, notebook, or science journal to help you stay organized.

Teams

You will be working with other classmates as part of a research team. Your team will conduct investigations and make decisions together. When conducting research, there may be many things to figure out as a team. You will need to be creative. There will not always be a clear right and wrong answer. Sometimes the team might not agree. This is okay. Just make sure to respect your teammates. There is no one right answer to the problems faced by your community. There is just the right answer for you and your team.

Getting Started

You will be thinking about complex problems. Sometimes this can feel difficult. Be patient. You will be guided to consider different parts of the problem. By the time you are making big decisions, you should have lots of information. Always remember, your work is important. Decisions you make can change your community. You are an important part of making your local and global communities better.

Thank you for working to make your community better.

The Smithsonian Science for Global Goals team
Smithsonian Science Education Center
Smithsonian Institution

Smithsonian | SCIENCE *for Global Goals*

OCEAN!

Part 1: Ocean Introduction

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Smithsonian Science Education Center greatly appreciates the efforts of all the individuals listed below in the development of *Ocean! How can we create a sustainable future for the ocean?* Part 1. Each contributed his or her expertise to ensure this project is of the highest quality. For a full list of acknowledgments please refer to the acknowledgments section at the beginning of this guide.

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PART 1: OCEAN INTRODUCTION

Find out More!

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

Part 1

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: What are our connections to the ocean?					
Discover	Develop a personal identity map showing the different parts of who you are and explore your connections to the ocean.	• Paper • Pens or pencils		45 minutes	6
Understand	Create an ocean identity map and gather oral histories about the ocean from your community.	• Class board or poster paper • Paper • Pens or pencils • Art and craft materials (optional)	*Personal Identity Map*	25 minutes + Oral history gathering time	9
Act	Design a museum exhibit to help others better understand the ocean and their connection to it.	• Paper • Markers, pens, or pencils • Art and craft materials (optional)	*Personal Identity Map* *Ocean Identity Map*	25 minutes	15
Task 2: What are ocean systems and why are they important?					
Discover	Use a system you are familiar with to create a system diagram.	• Paper • Pens or pencils		20 minutes	19
Understand	Investigate ocean systems from small to global, using pictures as a tool.	• Paper • Pens or pencils		25 minutes	24
Act	Consider different perspectives and create team goals for the future of the ocean. Use these goals to decide which guide parts you will use.	• Paper • Pens or pencils	*Ocean Identity Map*	25 minutes	28

Ocean! How can we create a sustainable future for the ocean?

In many ways, the **ocean** defines our planet. In this guide you will explore your connections to the ocean and how the ocean connects to you and your community.

While using the guide you will become an **action researcher** to identify and help solve problems in your community. Action researchers first ***discover*** their own existing knowledge, then they investigate to ***understand*** problems, and finally they ***act*** on what they have learned to make local and global communities better.

You will create and keep several sheets of paper or digital documents to help you record and remember information. You may want to use a notebook or folder to help organize the sheets you will use in the guide.

Remember: *In this guide you and your team are in charge. You can always change the instructions in the steps to make them work better for you and your team.*

Task 1: What are our connections to the ocean?

Who we are affects the way we think about and view the world around us. In this task you will first ***discover*** more about your own identity and how it has changed over time. You will then explore how your personal history connects you to the ocean. You will gather information from your community to ***understand*** more about the links between your community and the ocean. Finally, you will ***act*** by beginning to map out the ocean's identity.

Part 1 Task 1

Discover: *Who am I and how do I relate to the ocean?*

In this guide you will be exploring your connection to the ocean with the rest of your team. The ocean is the large body of saltwater that covers 71% of Earth's surface.

Before you can start to think about what the ocean is and how it connects to you, it is important to think about who you are. Our different experiences, backgrounds, and ideas give each of us a unique **identity**. Your identity is what makes you you. Each of us has a unique identity and a unique personal history. The ocean also has an identity and a history. Your personal relationship with the ocean is an important place to start this guide.

1. Take out a piece of paper or open a digital document and title it "Personal Identity Map."
2. Write your name in the center of the page or draw a small picture of yourself.
3. Think about your answer to the question, "Who am I?" The list below can give you some ideas to consider, but you choose what you think is an important part of your identity. You can also include things that are not on the list.
   - Age
   - School or class
   - Race and/or ethnicity
   - Gender
   - Country or place where you live
   - Country or place that is important to you or your family
   - Values or beliefs that are important to you
   - Goals that are important to you

- Topics or subjects that interest you
- Hobbies or things you like to do for fun
- Physical traits (such as tall, black hair, blue eyes, wears glasses)
- Personality traits (such as loud, funny, quiet, kind)
- Roles you have in your household (such as big sister, helper, cousin)
- Groups you belong to

4. Write or draw something on the page around your name to show the important parts of your identity.
5. Then draw a circle around all the things you listed as part of your identity. Figure 1.1 shows an example.

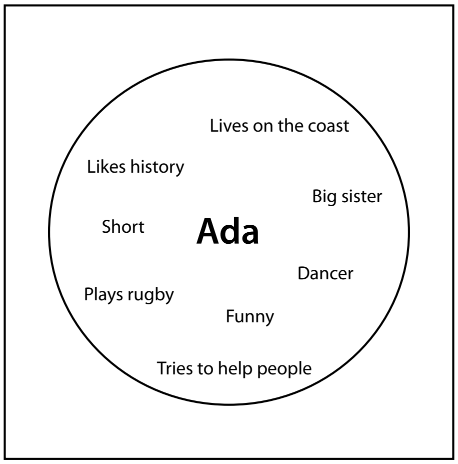

Figure 1.1: <u>Personal Identity Map</u> example.

6. Draw a circle around your *<u>Personal Identity Map</u>* and label the circle "Ocean Connections." Figure 1.2 shows an example. You will use this circle to help you think about your personal connections to the ocean.

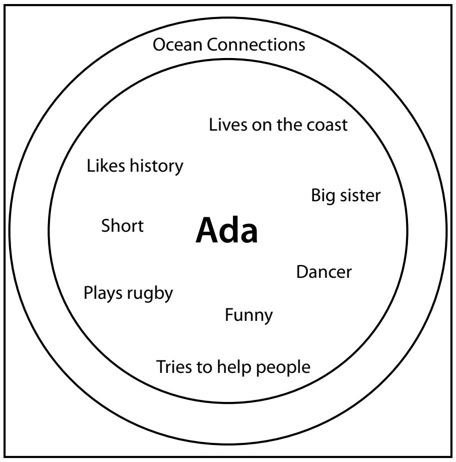

Figure 1.2: Example of a <u>Personal Identity Map</u> with the Ocean Connections circle added.

7. Examine the things you listed as part of your identity. Are there parts you think connect you to the ocean? For example, if you like to surf or you like to cook and your favorite food comes from the ocean, that could be a connection. Draw or write each connection in the *Ocean Connections* circle.
8. Think quietly to yourself about the feelings or beliefs that are part of your personal relationship with the ocean. Even if you have never physically been to the ocean, you still have a relationship with it. You may want to consider:
    a. How do you feel about the ocean?
    b. If you have been near the ocean, how would you describe that experience?
    c. What are your personal or cultural beliefs or stories about the ocean and the way people should relate to it?
    d. Are there specific words or language you or others in your community use to describe the ocean or parts of the ocean?
9. Write or draw each part of your relationship with the ocean in the *Ocean Connections* circle.
10. Think of an ocean-related memory and add it to your *Ocean Connections* circle. For example:
    a. Do you have a memory of being near, on, or in the ocean?
    b. Do you have a memory of experiencing the ocean through visual art, music, books, television shows, or movies?
    c. Is there a connection between your personal history and the ocean?
11. Turn to a partner.
12. Take turns telling your partner the story of your ocean-related memory, and listening to your partner's story.
    a. For the storyteller: Try to share details about your story and why you picked it.
    b. For the listener: Pay close attention and think carefully. Why is this story important and what does it tell you about how someone else thinks and feels about the ocean?

⚠ Emotional Safety Tip

Sharing memories can be very personal. Remember that your partner is trusting you to respect them and their memory. Make sure you listen carefully and stay open to the story, even if it feels unfamiliar or strange to you. If you are not comfortable sharing one memory, pick a different one to share.

12. Keep your *Personal Identity Map*. You will need it later.

Understand: *What is the relationship between the ocean and my local community?*

A ***community*** is a group of people who share something in common, for example, your family, your classmates, your teachers, or your neighbors. A community can share space, like a local, national, or global community. Or a community can share an identity, like a religion, ethnicity, or common interest. Some communities include many people and some have fewer people. If you think back to your identity map and your relationships, you will probably realize you are part of many communities.

Some local communities are located near the ocean and some are located farther away. But no matter where a community is located, the people in it still have a relationship with the ocean. In this activity you will find out more about some of those relationships.

1. Form a team. Your team may be your whole class, or it may be a smaller group. Either is fine. As action researchers, you will work together with your team, made up of your classmates, for the rest of this guide. You will work together to understand your local area and make it better.
2. Take out a very large piece of paper or use a class board or another shared space. Plan to leave this document or board on display while you are using this guide.
3. With your team, write or draw the word "Ocean" in the center of the paper, board, or area. Draw a circle around *Ocean* that takes up about half the space available. This is now your *Ocean Identity Map*.

4. Give each team member a marker, pen, or another way to write or draw their ideas on the *Ocean Identity Map*.
5. Within the *Ocean* circle, list anything you think is important to know or understand about the ocean. Add as many words or drawings as you want within the circle. For example you might want to list information about:
   a. The location of the ocean
   b. What the ocean is made of
   c. Parts of the ocean
   d. Types of things that happen in and around the ocean
   e. Living things in the ocean
   f. Ways the ocean is changing
6. Read *One Ocean*. If this information makes you want to add anything to your *Ocean Identity Map*, do so now.

One Ocean

You may have noticed the name of this guide is *Ocean*, not *Oceans*. But you also may know the names of different oceans, such as Pacific, Atlantic, and Indian. So why only one ocean?

Think of a map of the world. Is there any separation between the oceans you may be familiar with? No! Although we call different areas of the ocean different names, the water and living things in the ocean move and mix between these areas. Sometimes it can be helpful to think about different areas of the ocean, or **ocean basins**, by naming them separately. But it is important to remember that the ocean is all one connected whole.

7. Draw another circle around the *Ocean* circle on your *Ocean Identity Map* and label it "Connections." Figure 1.3 shows an example.

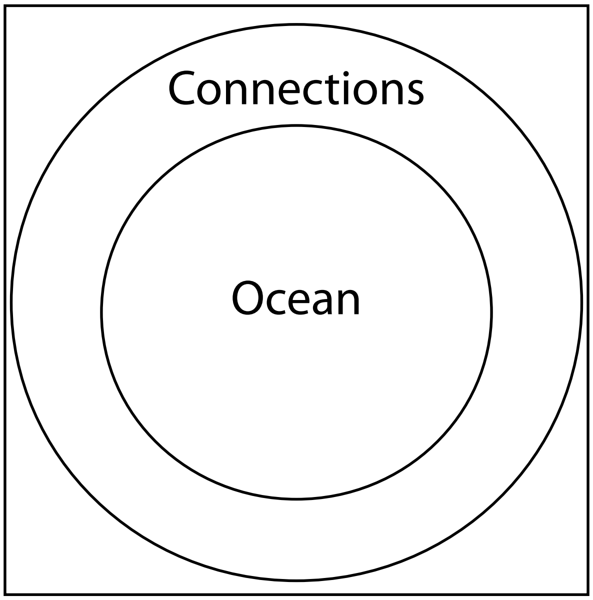

Figure 1.3: Example of an Ocean Identity Map with Ocean and Connections circles.

8. Have each team member add at least one ocean connection from their *Personal Identity Map* to the *Connections* circle in the team *Ocean Identity Map*.
9. Examine all the connections listed by the members of your team. Are there any that surprise you? Are there any that are similar to yours?
10. Discuss with your team:
    a. Why might it be useful to think about many different types of connections to the ocean when learning more about it?
    b. How can having different experiences with the ocean help your team as you do research?
11. With your team, decide which local community you will focus on and learn from as you research connections between your local community and the ocean. For example, you could choose the community of your town or your neighborhood or your school. Make sure it is a community your whole team is part of and a community you will be able to interact with. Choose a community that feels important and personal to you and your team.
12. Read the *Oral History Instructions*.

Oral History Instructions

When you talk to people and record information about their past, it is called an **oral history**. An oral history lets people share stories from their past. You can use these stories to gather information about the history of your community's relationship with the ocean.

You have already done this in a smaller way when you shared your ocean memory with your partner. Now each team member will gather an oral history of an ocean memory from your local community. Oral histories can have a lot of information. They can show changes over time, relationships, and what is important to a group.

Choosing People to Talk to

a. Think about who might know the most about the relationship of your community with the ocean. For example, it might be older people who have lived in the community a long time, a local historian, environmental activists, leaders who make decisions, or people who are part of a local **Indigenous** group. Indigenous means a group of people who lived in an area before any other groups arrived. Indigenous peoples are sometimes referred to as First People or First Nations, Aboriginal, or Native Peoples.
b. If you can, include people with many different identities when gathering community oral histories. As a team, try to talk to people with a variety of ages, genders, jobs, incomes, religions, ethnicities, roles in the community, or other identities. However, if this is too difficult, you can collect oral histories from communities that you are closer to, such as people in your school.
c. Think about the many ways people can share information and try not to leave people out.
d. Conducting oral histories can take a long time, so you may decide to talk to just one person. That is okay. If everyone on your team talks to at least one person, you will have enough information to complete the activity.

Possible Ways to Record an Oral History

a. You can use audio or video to record an oral history.
b. You can write or draw to make a record of the ideas that are shared with you.
c. You can talk to people in person, over the phone, or using the Internet.

Tips for Collecting an Oral History

a. Make sure you ask permission to record a person's answers to your questions.
b. Ask permission to share the oral history with the rest of your team, class, or other people in the community.
c. People might be more willing to talk if their oral history is **anonymous**.
d. A person may have photographs, drawings, or other **objects** that help them tell their oral history. Ask the person to describe the object and make sure you record their description.
e. If it feels like someone didn't answer your question, don't be afraid to ask the question again in a different way.
f. Let the person you are talking to answer the questions in the way they want. Be patient. Listen carefully. Understand that they might give answers that you didn't ask for.

Choosing Your Questions

Make a list of questions you would like to ask to help understand your community's relationship with the ocean. For example:

a. You might want to ask about ocean memories, like the ones you shared with your partner.
b. You might want to ask how people in your community think and feel about the ocean and if this has changed over time.
c. You might want to ask whether there are any community stories or strong beliefs about the ocean and its history or its living things.
d. You also might have other questions you want to ask.

Safety Tips for Talking to People

Talk to your teacher for guidelines. They will know what is safest in your community.

⚠ Physical Safety Tip

When gathering oral histories, always make sure you feel safe. You can always include a trusted adult or classmate when recording. You might want to suggest recording the oral history in a quiet public place.

⚠ Emotional Safety Tip

It can be hard to talk to other people in the community. You may feel shy or nervous. Someone may tell you they don't want to talk. That's okay! It doesn't have anything to do with you. It just means they don't want to share. You can show them respect by thanking them and moving on to another community member.

13. If an oral history doesn't sound like the right investigation for your team, you can pick another way to collect information about the relationship between your community and the ocean. For example, you could investigate using books, videos, maps, artwork, audio recordings, stories, or other records of the history of your community. Or you could gather information digitally, such as through a social media post.
14. Plan your investigation. Decide what needs to be done and who will do each part. For example, if you are recording an oral history, you will need to decide who will find people to talk to, who will talk to each person, and who will help record the oral history.

⚠ Emotional Safety Tip

People may tell stories that are difficult for them to talk about. Some stories might be hard for you to hear. People you talk to may also have opinions that you disagree with or that make you uncomfortable. It is okay to pause or stop a conversation if you are uncomfortable or upset.

15. Remember, including everyone is important. If you are working with a team, you may need to adjust the way you gather your oral histories so that everyone feels safe, comfortable, and able to help. Those changes are okay! They are part of including everyone. Make sure to consider:
    a. Time: If the investigation happens after school, does everyone in the team have time to do it?
    b. Comfort: If you decide to move around the community to gather your oral history, make sure everyone on your team feels safe and able to do this. If not, what is another way team members could help?
    c. Location: If the investigation is going to happen in a specific place, how easy is it for team members to get to that place?
16. Work with your team to gather the oral histories or investigate your community's relationship with the ocean in a different way.
17. Come back together with your team.
18. Listen to the histories gathered by your team.
19. Discuss with your teammates:
    a. What are the new things we have learned about the relationship between our community and the ocean?
    b. What are the most important parts of our community's relationship with the ocean?
20. Add words or drawings to represent the stories and ideas you learned about from your investigation to the *Connections* circle of your *Ocean Identity Map*.

Act: *How can we help our community connect to the ocean?*

You have learned that you have a lot of different parts that make up you and your identity. The ocean also has many parts that make up its identity. You have already begun mapping that ocean identity and its relationship to you and your community. Now you will use your senses and your knowledge to add to and share your ideas about the ocean's identity.

Part 1 Task 1

1. Imagine you were creating a museum exhibit to show people about the ocean and their connections with it. Use your *Personal Identity Map* and your *Ocean Identity Map* to help you think. By yourself, consider:
   a. What would you include? Are there certain objects or physical items that might help people realize their connection to the ocean?
   b. Are there certain parts of the ocean's identity that would be important to include?
2. Close your eyes and consider ways the ocean relates to your senses. How does it sound, feel, smell, taste, and look? You may have been to the ocean and be using your personal experience, or you may be using ideas you have gathered about the ocean from art, videos, games, music, or other sources. Either is fine.

> **Emotional Safety Tip**
>
> Some members of your team may not want to or be able to use all of their senses. This is not a problem. There are many ways to think about the ocean.

3. If you were creating a museum exhibit, how would you help visitors understand through their senses the experience of being at the ocean? For example:
   a. Sound: How does the ocean sound? Is there a way you could create the experience of the sounds of the ocean, such as a playlist of sounds?
   b. Feel: How do different parts of the ocean feel? Could you create an opportunity for someone to explore different ocean-related textures, like sand or seashells?
   c. Smell: What are the smells of the ocean? Do different parts of the ocean have different smells? How could you create that experience or describe it to someone else?
   d. Taste: What are the tastes of the ocean? Could you use words, pictures, or drawings to represent these tastes?
   e. Sight: What are the different sights or colors of the ocean? Think carefully about what the ocean might look like in different parts. How could you share that?

4. Read *At the Smithsonian* to learn more about museum exhibit design at the Smithsonian.

At the Smithsonian

Sant Ocean Hall is a large permanent exhibit at the Smithsonian's National Museum of Natural History. Why is it important to have a museum exhibit about the ocean? Ocean Hall exhibit developer Jill Johnson explains, "The ocean covers the majority of our planet, so it is the largest environment we have on Earth. There are a lot of human connections we have with the ocean. These connections can be very positive but can also be harmful. The health of the ocean is in danger."

Museum exhibits help communicate ideas. Jill says, "Sant Ocean Hall is a place where we can share information about the ocean itself, how important it is to our planet, and to our existence. We think the more people learn about the ocean, the more they are going to care about it. We want to give them the resources to be part of the changes that are needed."

Designing a museum exhibit takes careful thought. Developers learn about their audience and what they would like to know. Then they consider how to use objects to tell the story they want to share. Different people might find different things interesting, so exhibit designers try to create a variety of opportunities to have a personal connection to the exhibit.

Figure 1.4: Sant Ocean Hall at the Smithsonian National Museum of Natural History.

During this process, exhibit developers always keep in mind the big message. According to Jill, for Sant Ocean Hall that message is "The ocean is a global system essential to all life, including yours."

Think to yourself:

a. What is the big message you would want to share through your museum exhibit?
b. What objects could you use to help tell that story?

Visit the *Ocean!* StoryMap for more information on designing Sant Ocean Hall.

5. If you have time, work with your team to create your museum exhibit and share it with others in your community.
6. If you do not have time, use a piece of paper to draw or plan out your museum exhibit and share that paper with a friend, family member, or another person or group.
7. Ask the people you share your museum exhibit with, are there other connections they have to the ocean that are not part of the exhibit? If so, add those connections to the *Connections* circle on your *Ocean Identity Map*.
8. Keep your *Ocean Identity Map* safe. You will continue to add to it throughout this guide.

Task 2: What are ocean systems and why are they important?

The ocean is vast and complex. The ocean has many parts that affect one another. One of the best ways to understand the relationships between these parts of the ocean is to think about them as a **system**. A system is a group of individual items, living things, forces, or ideas that relate to one another. The parts of a systems often depend on one another and can be considered as an interconnected whole. The ocean is part of the systems of the Earth, and the ocean itself has many systems within it.

In this task you will first ***discover*** what you already know about systems and how they work. Then you will explore to ***understand*** different parts of the ocean system. Finally, you will ***act*** by deciding which parts of the ocean system are most important for you to understand so you can help protect the ocean in the future.

Discover: *What is a system?*

You are probably familiar with different systems. Some systems describe physical interactions or relationships between things. For example, you may know about systems in your body, such as your digestive system, in which many different body parts digest the food you eat. Or you may have heard of a system where living things and non-living things all interact in an area, such as an **ecosystem**. You might even know about large systems that span the entire planet, such as the water cycle. Systems have different parts that relate to and depend on one another.

In this activity you will think about how systems work. Understanding the idea of systems and their interactions will be very important to help you build your understanding about the ocean.

1. Read *Linking a System*.

Linking a System

You will start thinking about systems using what you know about relationships between a few items that might be familiar to you.

a. Take out a piece of paper and title it "Cooking Rice System Diagram." If you aren't familiar with how to cook rice, you can substitute pasta or potatoes for rice.

Figure 1.5: Picture of a system that might contain rice, water, salt, a pot, and heat.

b. Write the words "rice," "water," "salt," "pot," and "heat" around a page. Figure 1.5 shows an example. Remember if you prefer, you can substitute "pasta" or "potatoes" for rice.

c. Draw a box around each word. The boxed words represent **elements** or parts of a system. People, places, things, and ideas can all be elements in a system. The elements in the system you are considering are *rice*, *water, salt*, *pot*, and *heat*.

d. Examine your five elements. Are there ways you think these elements could be linked to create a specific **result** or outcome connected to the process of cooking rice?

e. For each link you noticed in the system, draw an arrow to show the **relationship** between the two elements. A relationship is how two or more elements in a system are connected to or affect one another. Sometimes there is only one relationship or arrow connected to an element. Sometimes there

Part 1 Task 2

are several. If the relationship goes both ways, you can draw two arrows, one pointing in each direction. The arrows in Figure 1.6 are just examples. The relationships you identify might be different.

f. Write words to label each arrow to explain the connections around the process of cooking rice. For example maybe between rice and pot you might write "the rice goes in the pot."

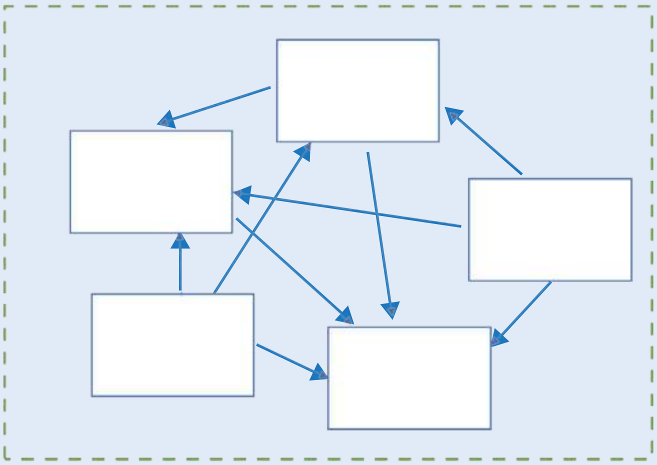

Figure 1.6: Example of a Cooking Rice System Diagram.

Congratulations! You just created a **system diagram**. A system diagram is a way of showing the elements and relationships in a system so you can understand how the system works. It can also help you understand what is happening when a system changes. In this guide you will be creating system diagrams about ocean systems. You will use these diagrams to learn more about problems or changes to these systems.

Do not worry if your system diagrams seem complicated or messy. Systems in the real world are often quite complex!

2. Turn to a partner and show them your system diagram.
3. Examine your two system diagrams together. Did you both show the same relationships between the elements? Don't worry if you listed different relationships; there can be multiple relationships between elements of a system.
4. Read *Bounding a System*.

Part 1 Task 2

Bounding a System

Think about the system you just drew. Does it connect to other things around it? Of course! Each element of the system connects to other systems. For example, the water may have come from a tap that connects to a pipe that connects to a larger system of pipes. The system of cooking rice is also contained within other systems, such as the system of someone cooking dinner in a kitchen.

If you added all the possible elements and relationships together at once, the system becomes very complex. This can make it difficult to understand and identify problems. That is why people often use boundaries when thinking about systems. A **boundary** is just a way of defining exactly what is part of the particular system you are thinking about. This can help you identify problems within the system.

a. Draw a dashed rectangle or circle that surrounds your system diagram. This dashed shape represents the boundary of your system. The dashed line in Figure 1.6 shows an example of a system boundary.

Problem-Solving Using Boundaries

Now you will put the power of system boundaries into action to help solve a problem. Imagine if your cooked rice (or pasta or potato) is too hard. What could have gone wrong?

b. Examine your system diagram. For each relationship, think about whether a problem in that relationship could have led to the result of hard rice. For example, could hard rice be the result of a problem between the rice and the water? The pot and the heat? Two other elements?
c. Identify and circle each arrow that shows a relationship that might be a problem.
d. Share your answers with a partner. Did they notice any potential problems with relationships that you didn't?
e. If you are trying to solve a problem, why might it be useful to use a system with a set boundary?

5. With your partner or team, discuss what would happen if you drew a bigger boundary around your system.
    a. What things might be included within that bigger boundary?
    b. Imagine you were trying you were trying to solve the problem of hard rice and you realized there was no water. Would you need to draw a bigger boundary to understand the problem of no water to cook rice with?
6. Read *System Removals and Additions*.

System Removals and Additions

Most systems are open, meaning that elements can enter or exit the system. Those entries and exits can change the system.

Removals

In this guide we will call elements that are removed from or leave the system **removals**.

a. Examine your *Cooking Rice System Diagram* and imagine you removed one of the elements. What would change about the system if that element was not there?
b. One at a time, think about the removal each of the other four elements. How would the system change?
c. Discuss with a partner:
    - Which elements would completely change the system if they were missing?
    - Are there some elements that would change the system less?

Additions

Elements that are added to or enter a system are called **additions**.

a. Examine your *Cooking Rice System Diagram* and think of one additional element that could be added to that system. For example, could something else be added to the pot?
b. Think to yourself, what would change about the system with the new addition?

c. Discuss with a partner:
   - What are some new additions you can think of for this system?
   - Additions can be an entirely new element or they can be more of an existing element. For example, if the addition was twice the amount of water, how do you think that might change the system?

System additions and removals can be added to system diagrams. Figure 1.7 shows an example of how to diagram additions and removals. Add one of the additions and one of the removals you just considered to your *Cooking Rice System Diagram*.

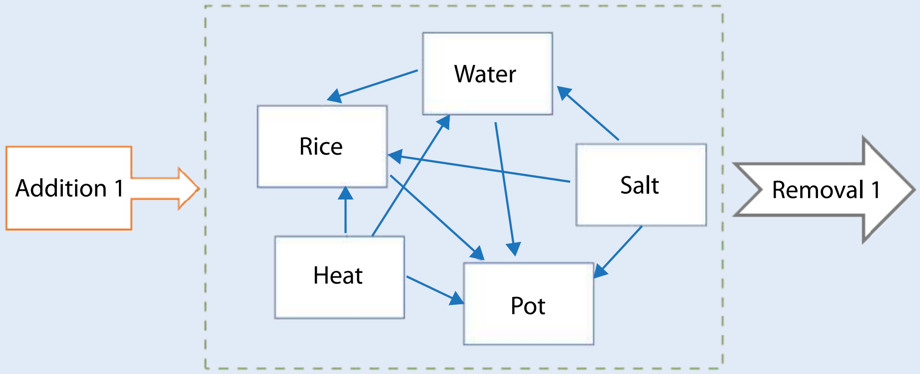

Figure 1.7: Example of a system diagram showing additions and removals.

7. Remember how to make a system diagram. You will have a chance to make and use more diagrams about ocean systems in the next activity and as you continue through this guide.

Understand: *What systems are part of the ocean?*

The ocean system is complex and always changing. It has many systems within it and is part of many systems of our planet. There are some ocean systems that are **localized**, or only found in a specific place in the ocean, and there are some systems that span the whole ocean. In this activity you will analyze different types of ocean systems.

1. Have each team member take out a piece of paper.
2. Fold your paper into thirds.

3. Examine Figure 1.8, the close-up picture of a **rock pool**, a small area next to the ocean. A rock pool can also be called a tide pool. Some of the time a rock pool is underwater. However, when the tide goes out, the water and the organisms in the rock pool are separated from the ocean.
4. In the first third of your paper create a rock pool system diagram. You can use Figure 1.6 to help you remember how to draw a system diagram.
   a. First, add the elements. Pick up to five elements you notice in the rock pool system. Keep in mind that some elements can be easy to forget, like water, rocks, air, or sunlight. Draw a box around each element.
   b. Second, add arrows to show the relationships. How do the elements connect to or affect one another? Label each arrow to show the relationship. Do not worry if you don't know all the relationships, just do your best.
   c. Third, add the boundary. What is the boundary of the system you are examining. Add and label a dashed line to show the boundary.

Figure 1.8: Close-up of a rock pool by the ocean's edge.

5. Examine Figure 1.9, the close-up picture of a **coral reef**, an ecosystem that includes individual corals, fish, and many other species all living together in the same area.
6. In the next third of your paper, create a coral reef system diagram. Just as with your rock pool system diagram, add the elements, the relationships, and the boundary. Remember people can be part of systems. You can use the directions in step 4 or Figure 1.6 to help you.

Figure 1.9: Coral reef ecosystem.

7. Examine the **coast** of an ocean shown in Figure 1.10.
8. Use the final third of your paper to create a coast system diagram. Just as before, add your elements, relationships, and boundary.

Figure 1.10: A coast where the ocean and land meet.

10. Examine the three system diagrams you created and discuss with a partner:
    a. Are there any elements that are part of more than one system?
    b. Can you think of any connections between the elements of the different systems?
    c. Are there other boundaries you could use that would pull together elements from more than one system?
    d. When thinking about a system, are there some relationships that might be easy to miss, depending on where you place your boundary?

11. Read *At the Smithsonian* to learn more about how Smithsonian scientists are **collaborating** or working together to explore ocean systems around the world. Why do you think it might be useful to compare data collected about ocean systems with different system boundaries?

At the Smithsonian

Smithsonian scientists know that understanding ocean systems takes a lot of collaboration. That is one reason for the Smithsonian's Marine Global Earth Observatory (MarineGEO) Network. Through this network, partners at research stations around the world's coastlines work together using the same methods to collect the same types of data about important coastal marine life and ecosystems, such as seagrasses, coral reefs, and oyster reefs. They focus on these coastal places because most marine species and most people live near the coasts. Coastal ecosystems are important to the health and survival of both humans and marine life. MarineGEO partners share and analyze their data to track changes to coastal marine ecosystems and the benefits they provide to people.

Figure 1.11: A MarineGEO researcher observes a coral reef.

Part 1 Task 2

Monitoring coastal life and ecosystems helps MarineGEO researchers discover the ways the ocean is changing. MarineGEO researchers also work together to understand the reasons for those changes. For example, MarineGEO recently teamed up with researchers from other Smithsonian museums and institutes, and colleagues from across North and South America, to investigate how warming sea temperatures and the declining numbers of fish in the ocean affect other marine organisms. They are conducting an experiment at sites from near the Arctic in the north all the way to the tip of South America. The team concluded that at higher temperatures, taking fish away has a bigger impact on the sea-bottom ecosystems.

Bringing data together from places all around the ocean helps researchers understand the whole system of the ocean and how and why it is changing, in ways that no one could do alone.

Act: *What can we do to encourage a positive future for the ocean?*

People have an important relationship to the ocean and its systems. People affect the ocean and the ocean affects people. This relationship can be considered from many different **perspectives**, or ways of thinking about the world around us. In this activity, you will think about what might make a **sustainable** relationship between people and the ocean. Sustainable means an approach that balances different perspectives and can keep working for a long time.

1. Choose a three-dimensional object around you, such as a chair or table.
2. Have different team members examine the object from different angles and share with the team exactly what they notice. For example, maybe one person examines the object from below, one from the side, and one from the top.
3. Have different team members touch different parts of the object and describe to the team what they feel. For example, maybe one touches a metal table leg and another touches the edge of the table and another the tabletop.

4. Discuss with your team:
    a. What different information did the different team members share about the object?
    b. What would you be missing if you only used one perspective?
    c. How does this activity show why thinking about different perspectives is important?
5. Read *Different Perspectives*.

Different Perspectives

Just as there can be different perspectives that come together to understand an object, it is also important to consider different perspectives to understand a situation.

For a situation to be sustainable, it needs to be balanced. This means it cannot just satisfy one person or group; it needs to balance the needs of people, other living things, and our planet. When thinking about sustainability, it is important to consider at least four types of perspectives: social, economic, environmental, and ethical.

- **Social** is about the interaction of people in a community. The health, education, cultural and community ties, and well-being of people are the most important things from this perspective.
- **Economic** is about money, income, and use of wealth. Economic growth, including making sure people have jobs and enough money, is the most important thing from this perspective.
- **Environmental** is about the natural world. Protecting living things, natural systems, and Earth itself are the most important things from this perspective.
- **Ethical** means that something is fair. Doing what is right and having a just community where everyone and everything is treated fairly are the most important things from this perspective.

6. With your team, take out a piece of paper and divide it into four sections. Label these sections "Social," "Economic," "Environmental," and "Ethical."

7. Examine your *Ocean Identity Map* carefully. What **themes** or main ideas do you notice about important parts of or connections with the ocean from each perspective? For example, maybe you notice that many people use the ocean as a source of peace or a place to have fun. That theme would be part of a social perspective.
8. Write the themes you notice in the section of the perspective they represent.
9. Take out your *Ocean Identity Map* and add two more circles. Label them "Concerns" and "Hopes." Figure 1.12 shows an example.

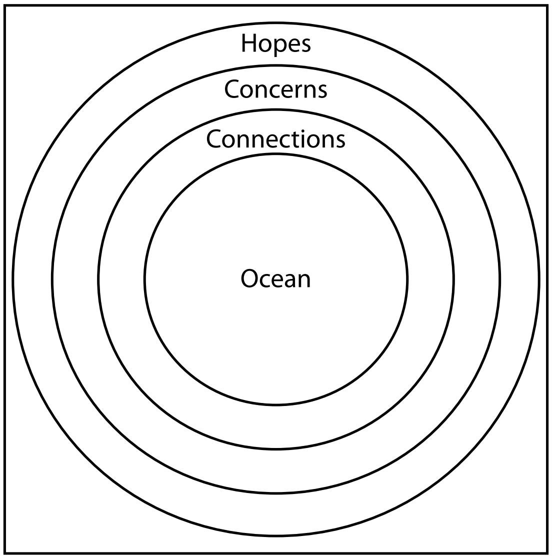

Figure 1.12: Example of an Ocean Identity Map with all four circles added.

10. Examine the themes you have written for each perspective.
    a. Are there concerns you notice from each perspective? If so, write those down in the *Concerns* circle.
    b. What would be your hopes for the future of the ocean from each perspective? What would a perfect future for the ocean be from each perspective? Write your ideas in the *Hopes* circle.
11. If there are other hopes or concerns you have about the ocean, add those to the *Hopes* and *Concerns* circles now.
12. With your team, use the hopes and concerns you just listed to think about important goals for a sustainable future for the ocean. These goals might be based on your hopes for something to continue, like "people can continue to rely on the ocean as an important source of food," or they might be based on changes you would like to see, like "plastic pollution of the ocean is stopped." These are your *Ocean Goals*.

13. List these *Ocean Goals* in the space outside the *Hopes* circle of your *Ocean Identity Map*.
14. Read *The United Nations and the Sustainable Development Goals*.

The United Nations and the Sustainable Development Goals

Achieving a sustainable future like the one you just thought about is complex. It takes many people working together in many places to create a sustainable future. When many people are working together, it helps to have someone organizing. The United Nations, also called the UN, is a global organization designed to help governments and people around the world collaborate.

As the year 2015 approached, the UN asked countries and people around the world to imagine a better world and a better future. They worked together to determine a list of goals. Then the countries of the UN came to **consensus** on the most important goals needed to get to a better world. These goals for the global community are called the UN **Sustainable Development Goals**, or SDGs. The SDGs are the global goals designed by people across the world to last from 2015 and 2030.

Figure 1.13: United Nations Sustainable Development Goals.

15. Examine the different SDGs. Are there SDGs you think are important for a sustainable future for the ocean and for people that your team didn't list in your *Ocean Goals*? Do you think those goals are also important? If so, add these goals to your *Ocean Goals* listed on your *Ocean Identity Map*.
16. Read *Picking a Path*.

Picking a Path

To work toward your *Ocean Goals*, what is it most important to learn about? You have almost completed Part 1 and you will want to complete Part 7 at the end.

Parts 2 through 6 of this guide can help you explore sustainability and different ocean systems. Parts 2 through 6 are about:

Part 2: Ocean and Water: Exploring the movement of the water system on Earth and in the ocean and how that relates to ocean pollution.

Part 3: Ocean and Air: Exploring the chemistry of ocean systems involved in the changing acidity of the ocean and how that affects living things in the ocean.

Part 4: Ocean and Heat: Exploring how the ocean system absorbs and redistributes heat on Earth and what a warming ocean means for people and ocean systems.

Part 5: Ocean and Food: Exploring the system of ocean food webs and how to make human activities harvesting and fishing sustainable.

Part 6: Ocean and Coasts: Exploring the meeting of human and ocean systems along the ocean's coasts and how to balance the needs of both people and the ocean.

Part 7 will help you bring together what you have learned so you can plan and implement actions to protect ocean systems.

17. Find out from your teacher or other leader how many parts you have time to do.
18. If you do not have time for all the parts, discuss with your team and pick the parts that are most closely related to your *Hopes, Concerns*, and *Goals* for the ocean.
19. Work with your team and choose which parts you will do next.

Congratulations!

You have finished Part 1.

<u>Find out More!</u>

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

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.

Action researcher: A person who works with their community to discover, understand, and act on local and global problems they learn about

Additions: Things that are added to or enter a system

Anonymous: People do not list their name

Boundary: The edge or border of a system

Coast: The area where the ocean and the land meet

Collaborating: Working together

Community: A group of people who share something in common, such as a space or an identity

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

Coral reef: An ecosystem that includes individual corals, fish, and many other species all living together in the same area

Economic: About money, income, and the use of wealth

Ecosystem: A system where living things and non-living things all interact in an area

Element: A part of a larger system

Environmental: About the natural world

Ethical: Something that is fair

Identity: The characteristics that make you you

Indigenous: A group of people who lived in an area before any other groups arrived; Indigenous peoples are sometimes referred to as First People or First Nations, Aboriginal, or Native Peoples

Localized: Only found in a specific place

Object: A physical item

Ocean: The large body of saltwater that covers 71% of Earth's surface

Ocean basins: Different areas of the ocean

Oral history: Recording information from people who are talking about their past

Perspectives: The different ways we think about the world around us

Relationship: How two or more elements in a system are connected to or affect one another

Removals: Things that leave or are removed from a system

Result: The outcome

Rock pool: A small area that is underwater part of the time on the edge of the ocean; also known as a tide pool

Social: Relating to the interaction of people in a community

Sustainable: An approach that balances different perspectives and can keep working for a long time

Sustainable Development Goals (SDGs): Seventeen goals for a better world created by the countries of the United Nations

System: A group of natural things or forces that interact with one another as part of a common network

System diagram: A way of showing the elements and relationships in a system so you can understand how the system works

Themes: Main ideas

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for Global Goals

OCEAN!

Part 2:

Ocean and Water

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian
Science Education Center

in collaboration with

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the interacademy partnership

Smithsonian Science Education Center greatly appreciates the efforts of all the individuals listed below in the development of *Ocean! How can we create a sustainable future for the ocean?* Part 2. Each contributed his or her expertise to ensure this project is of the highest quality. For a full list of acknowledgments please refer to the acknowledgments section at the beginning of this guide.

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PART 2: OCEAN AND WATER

Part 2

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 does water move around our planet?					
Discover	Search for elements of your community's water system and map your watershed.	• Paper • Pen or pencil • Digital or physical map of your area	*Ocean and Water System Diagram*	40 minutes	43
Understand	Model surface currents and analyze a map of global ocean currents.	• Shallow basin, preferably clear • Water • Ground pepper or small bits of paper • Rock or similar item (optional)	*Ocean Identity Map*	30 minutes	50
Act	Connect ideas about local and global water systems and share what you have learned.	• Paper • Pencil	*Ocean and Water System Diagram* *Ocean Identity Map*	20 minutes	55

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How do circulating water pollutants affect our planet?					
Discover	Model types of water pollution and search for evidence of pollutants in your community that may be affecting the ocean.	• Shallow basin, preferably clear • Water • Flat, waterproof surface • Piece of scrap plastic • Scissors • Watering can or cup • Cooking oil • Food coloring • Sponge • Salt or sugar (optional) • Paper • Pen or pencil	*Ocean and Water System Diagram*	30 minutes + community investigation time	57
Understand	Investigate the impact of water pollution on ocean organisms.	• Paper • Poster board (optional) • Pen or pencil	*Ocean Identity Map*	25 minutes	63
Act	Determine which pollution problem you would like to help solve and take action.	• Paper • Pen or pencil	*Ocean Identity Map* *Ocean and Water System Diagram*	25 minutes + action time	72

Part 2 Planner

Meet Your Research Mentor, Dr. Kālewa Correa

Meet Dr. Kālewa Correa. Kālewa (pronounced *KAH-lev-ahh*) will be your research mentor to help you understand more about the movement of the water in the ocean.

Kālewa is the Curator of Hawai'i and Pacific at the Smithsonian Asian Pacific American Center. Kālewa has a doctoral degree in learning design and an undergraduate degree in Hawaiian studies. He also managed the Mokupapapa Discovery Center for many years to help visitors connect with the ecosystems of the northwestern Hawaiian Islands and surrounding marine environments. Since Kālewa is now working with you, it is important to understand who he is.

Part 2

Kālewa's Identity Map

- Kānaka Maoli (Native Hawaiian) and Cook Islands Māori ethnicity
- Azorean Portuguese, Scottish, Irish, and English ethnicity
- Historian, researcher, musician, and futurist
- Male
- 48 years old
- Lives in Hawai'i
- Interested environmental systems
- Have played guitar, bass, and synthesizers for over 30 years
- Interested in history, art, music, human potential, and future studies
- Have traveled to some of the most remote places in the Pacific
- Studied learning design and Hawaiian studies
- 1.85m (6'1") tall, brown eyes, dark brown and grey hair
- Naturally an introvert but have a jokester side
- Father to two young girls, 9 years and 12 years
- Husband to my wife of 20 years
- Enjoy growing my food and being the household cook
- Balance and justice are the two most important values to me.
- I look to the past to help me live in a *pono* (balanced) way.

Task 1: How does water move around our planet?

In this task you will ***discover*** the water system in your community. You will model the ocean to ***understand*** what happens to water when it reaches the ocean. Then you will ***act*** to share this information with others.

Before you begin the rest of Part 2, think quietly to yourself about Kālewa's identity map and compare it to your *Personal Identity Map*.

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

Throughout Part 2 you will notice Kālewa sharing ideas and experiences with you. He may help you understand better ways to do your research or share some of the research he has done.

Discover: *How does water move through my community?*

Where does the water around you come from and where does it go? Water circulates between the land, the ocean, the atmosphere, and the **cryosphere**, or places on Earth where water is frozen, such as in glaciers. In this activity you will think more about how this system works and how it links to your community.

1. Read *Searching for Elements of Your Community's Water System* and follow the directions.

Searching for Elements of Your Community's Water System

Choose an area around you that you would like to investigate. This could be your city or town, your neighborhood, or another local area. If you can, move around the area you picked to find places that hold or channel water as part of the water system. If that is not possible, you can use your memory, online pictures or maps, or other resources.

a. With your team, take out a sheet of paper or open a digital document and title it "Ocean and Water System Diagram." Remember what you learned in Part 1 about creating a system diagram.
b. Divide your paper in half. You will diagram the water system in your local community on the top half. Later you will use the bottom half to diagram the water system of Earth.
c. Move around different spaces and try to notice things that use, move, or store water. Figure 2.1 shows some ideas. If you can, search for:

- Indoor elements: for example, a sink or washing machine.
- Outdoor elements around your building: for example, gutters on the side of the building or rain barrels.
- Elements that are other built places in your local area or community: for example, are there pipes, street gutters, storm drains, or drainage ditches that channel water?
- Elements that are natural areas in your community: for example, a stream or pond or **groundwater**. Groundwater is water found underground in the soil or in spaces between rocks.

Figure 2.1: Examples of places with water in a community.

Part 2 Task 1

d. As you search for parts of the water system in your community, pick at least four things you find and write them down in the top half of your _Ocean and Water System Diagram_. Draw a box around each word to show it is an element in your community water system, Figure 1.6 shows an example, if you need to remember how to create a system diagram.

2. In your _Ocean and Water System Diagram_ draw and label arrows to show how water moves between elements. For example, maybe groundwater is pumped out of a well and into the sink in your house, then goes down the drain and through the pipes to a water treatment plant. You could draw arrows and add labels to show the connection between the groundwater, well, sink, pipes, and water treatment plant. Figure 2.2 shows an example of how that system diagram might appear. The system diagram of your community will be different. Draw as many arrows as you need, but do not worry if you do not know all the ways water flows around your community. Just do your best.

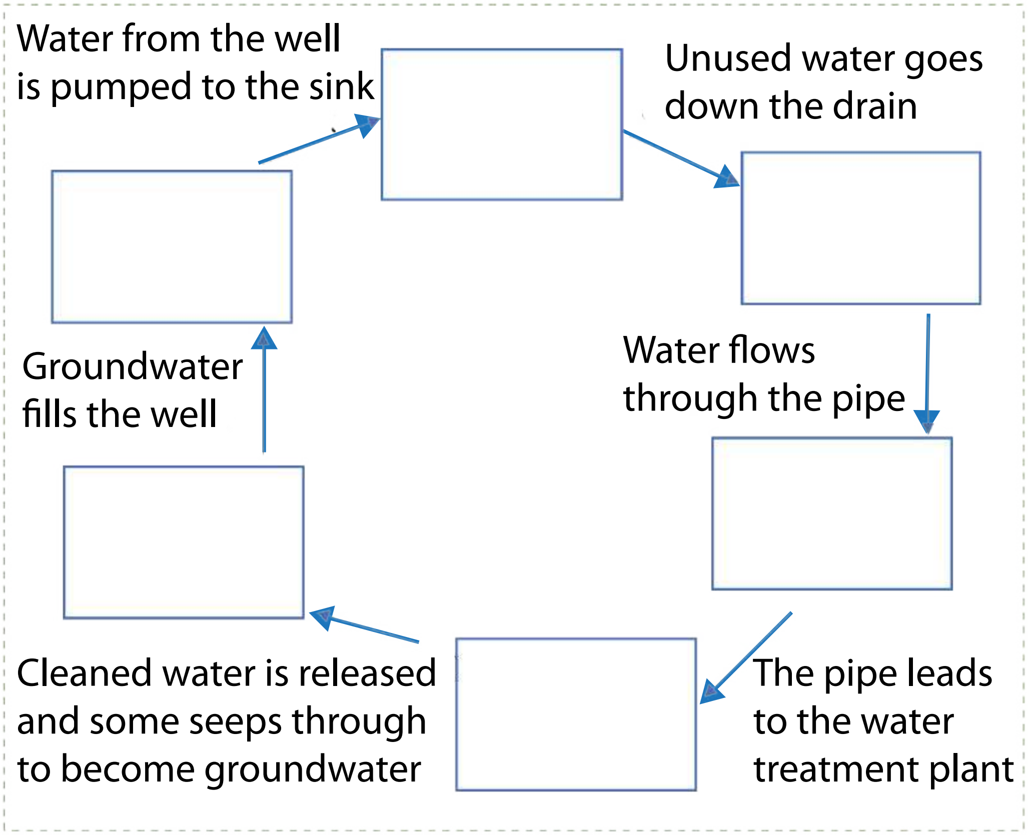

Figure 2.2: Example of a Community Water System Diagram showing elements and relationships.

Part 2 Task 1

3. Draw a large box with dashed lines around all the elements to show the boundary of your community water system.
4. Discuss with your team:
   a. What are the *Additions* to our community's water system? Where does the water come from? For example, from rain or a river.
   b. What water leaves our community's water system? How does it leave? Water leaving the system is a *Removal*.
5. Add any *Additions* or *Removals* you can think of. Use the sample system diagram in Figure 2.3 to help you.

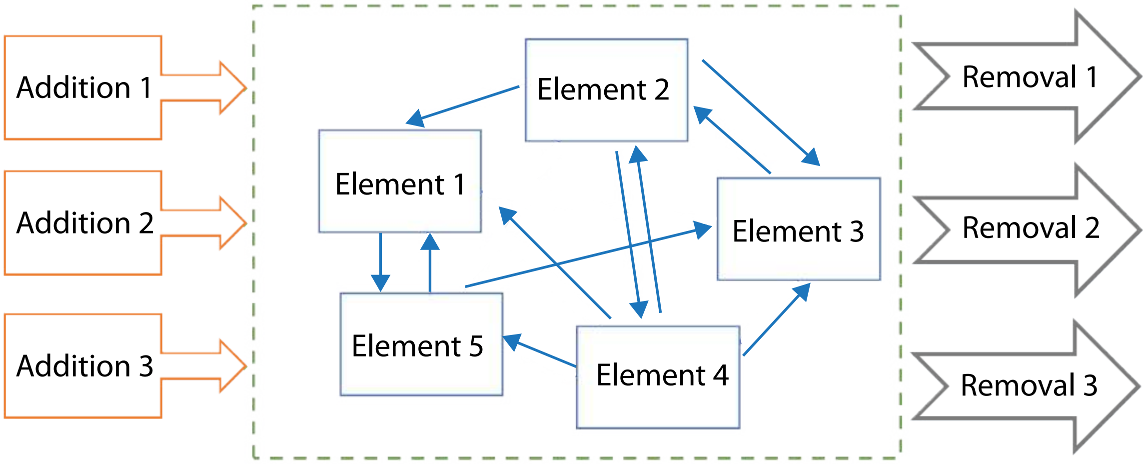

Figure 2.3: Sample system diagram showing Additions and Removals.

6. Read and carry out the instructions in *Mapping Your Watershed*.

Mapping Your Watershed

a. Open a digital map of your area or find a map you can draw on.
b. Think about places where you have noticed water flowing in your community, such as a river or stream. Which direction was the water flowing? Water can flow into your community from **upstream**. Water can flow out of your community to **downstream**. If you need more information, you can go to place where water is flowing or use a video of that place to examine the direction of water flow.

Part 2 Task 1

c. Use the map to try to trace any water flowing through your community back to its **source**, which is where it came from. For example, if there is a river in your community, follow it upstream on the map and notice which communities it flows through. Usually upstream is going to be away from where the water reaches the ocean.

d. Mark any **tributaries**, or smaller streams, creeks, or rivers that joined the water before it reached your community. Circle any towns or cities it flows through.

e. Add the names of all of your marked **waterways** as *Additions* on your *Ocean and Water System Diagram*. In this guide, the word "waterway" is used for any flowing water, such as a river or stream.

f. Use the map to try to trace and mark any water flowing out of your community downstream. Where does water flowing from your community eventually go? Follow it as far as you can. Circle any towns or cities it flows through.

g. Add each body of water flowing out of your community as *Removals* on your *Ocean and Water System Diagram*.

h. Examine the tributaries that meet with water from your community on its way to the ocean. Try to follow and mark each tributary as far as you can. Sometimes bodies of water do not reach the ocean. That is okay. Just note down where the water from your community goes.

i. Draw a circle around the whole area you have just marked. This is your **watershed**, an area of land where all the water flows together into the ocean.

7. Discuss with your team the connections between you and the other people and living things in your watershed.
   a. Which town's water system removals might be the additions to your community's water system?
   b. Examine the circled towns or cities that are upstream. How do the choices made by people upstream affect you?
   c. Which town's water system additions might be the removals from your community's water system?

d. Examine the circled towns or cities that are downstream. How do your choices affect people downstream?

e. What might feel unfair or difficult about a system where people's choices in one place might affect people in another distant place?

8. Read Kālewa's thoughts about the relationship between people and **ecosystems** in their shared water system.

Kālewa says . . .

The *kānaka maoli* (Native Hawaiian) traditional land division was known as the *ahupua'a*. The divisions are generally wedge-shaped areas stretching from the uplands to the sea, integrating the natural resources and geographic features from mountain to ocean. This land system showcases nature's and humans' interconnectedness. Every *kānaka* (Hawaiian person) in the *ahupua'a* had specific roles in ensuring the health and sustainability of the entire system. Those living *mauka* (upland) knew their actions affected their neighbor's *makai* (toward the sea).

Wai (fresh water) is viewed as a communal resource, and its equitable distribution is very important. Water and land are considered ancestors and *'ohana* (family) within the Native Hawaiian culture. The Native Hawaiian philosophy is that water is a shared resource and must not be hoarded or wasted. Any changes or disturbances upstream would directly influence the resources and livelihoods downstream. For example, if forests were cleared carelessly or overharvested, it could lead to erosion and sedimentation, affecting the coral reefs and fisheries downstream.

Native Hawaiians have had a deep understanding of the intricate relationships within and of their ecosystems that have spanned thousands of years within the Hawaiian Archipelago.

9. Read *The Water Cycle* and follow the directions.

The Water Cycle

Not all water stays in the ocean. It can also move through other parts of the **water cycle**. Water from the ocean evaporates into the atmosphere, condenses to form clouds, and eventually falls again on land and in the ocean as rain, snow, or other types of precipitation. Figure 2.4 shows a representation of the water cycle.

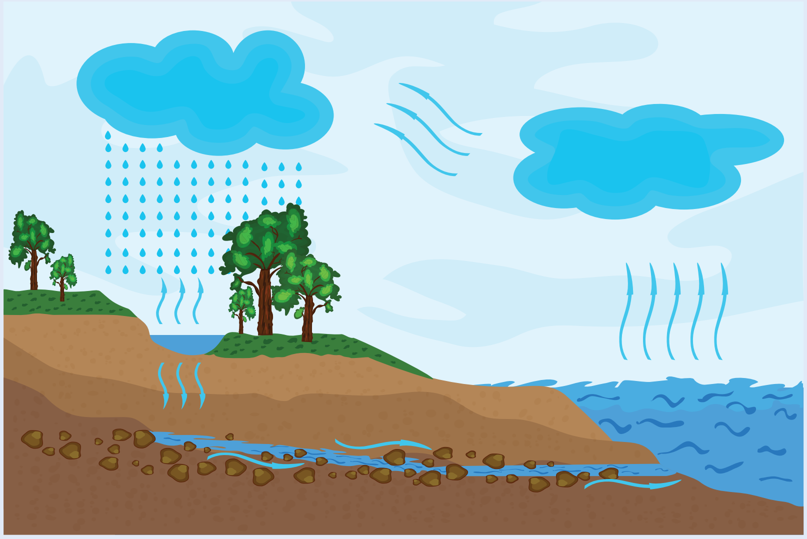

Figure 2.4: The water cycle includes precipitation from clouds, water in a lake, river, and groundwater, water moving to the ocean, evaporation from the ocean and lakes, condensation into clouds, and then clouds moving over land.

a. On your *Ocean and Water System Diagram,* add elements from Earth's water cycle to the bottom half of your paper. Be sure to add elements to show how water reaches, moves around, or leaves the ocean.
b. Draw and label arrows to show relationships between the parts of the water cycle. For example, you might use the words "evaporation" or "precipitation" to show how water is moving through the system.
c. Examine your diagram. Can you use arrows to connect your community water system's removals with the additions by using parts of the water cycle?

Even if you are far away from the ocean, it is very likely that precipitation falling on your community evaporated from the ocean. Around 86% of global evaporation comes from the ocean. Evaporation creates water vapor in the air and condenses to form clouds. These clouds travel over land and drop the water in the form of precipitation.

***Understand**: How does water move around the surface of the ocean?*

Water does not stop moving when it reaches the ocean. In fact, there are **currents** similar to rivers within the ocean. A current is when water flows in a specific direction. Ocean water moves horizontally in currents along the surface of the ocean. It also moves vertically in currents between the deep ocean and the surface. On the surface, water evaporates out of the ocean, providing most of the water vapor found in the air and clouds. In Part 4 you can learn more about deep water currents within the ocean. In this task you will concentrate on surface currents.

Sometimes people use the word "ocean" to refer to a geographic area or **ocean basin** within the larger ocean, such as the Pacific Ocean. But this is a little misleading. All the areas of ocean on Earth are connected. So they are all one ocean of water moving and mixing. Water flowing into one part of the ocean will eventually travel to other parts. In this activity you will think about why this movement is important. Then you will model some of the reasons ocean water moves and mixes.

1. Think to yourself, why is it important to people that water moves around in the ocean?
2. Read Kālewa's description of the significance of the ocean to the people of the Pacific Islands. What stands out to you as important to remember? Add anything related to the way people connect to the ocean to the *Connections* circle on your *Ocean Identity Map*.

Kālewa says . . .

The movement of ocean water has a profound impact on the cultures of the Pacific islands. For these island communities, the ocean is not just physical; it's a big part of their way of life. Imagine this: The sea is like a teacher and a provider. It taught their ancestors how to navigate the vast Pacific using stars and currents, a skill passed down for generations. It's a central character in their stories, dances, and daily life, especially in activities like fishing. The ocean is like a family member—it's always there, shaping their traditions, guiding their way, and giving them what they need.

But there's another side to this story. As the ocean moves, it also affects the weather. Weather can be suitable for farming and fishing, but it can also bring storms and rising sea levels. Recently, climate change is making the ocean rise, which can be a real danger to these islands. So for these communities, the ocean isn't just a part of their culture; it's a challenge they face, too. They must adapt and find ways to protect their homes while keeping alive their deep connection to the sea.

3. Discuss with your team: What are the things you can think of that might cause ocean water to move? Write down or find some other way to record your ideas. You will think about them again at the end of this activity.
4. Read and follow the instructions in *Surface Current Modeling*.

Surface Current Modeling

Surface currents are the horizontal movement of water in the first 50 to 100 meters near the ocean's surface. What do you think might be causing this movement?

a. Take out a long, shallow container and fill it about halfway with water. If possible, use a clear plastic or glass container to make it easier to observe. Figure 2.5 shows an example.

Figure 2.5: Example of a current model setup.

Part 2 Task 1

b. Examine the water in the container. Other than moving the container, how could you make the water move without touching it?
c. Try out any ideas you might have.

You may have thought about blowing across the water to move it. This is similar to wind blowing across the ocean and is one of the major causes of surface currents.

Are you familiar with the jet stream, the tradewinds, or the westerlies? They are all **prevailing winds** on Earth. This means they are important winds that blow in the same general pattern and direction.

The strongest sunlight hits Earth's land and water in the **tropics**. As the air in that region is warmed, it rises into the atmosphere and moves toward the cooler poles of Earth. At the same time, Earth's rotation causes air moving just above the equator to move to the right in the northern hemisphere and to the left in the southern hemisphere. This is called the **Coriolis effect**. The combination of movement of air from the tropics toward the poles and the Coriolis effect means that winds generally rotate in a clockwise direction to the immediate north of the equator and counterclockwise (or anticlockwise) to the immediate south.

And as you have just learned, surface ocean currents often move in the same direction as the prevailing winds. When ocean currents rotate in these circular patterns, they are called **gyres**.

a. Try to model a gyre by having two people blow in opposite directions from opposite sides of your container.
b. Observe the water in the container. Which part of the water is moving the most? What happens to the water in the center?
c. Float something light, like ground pepper or a few small bits of paper, on the water and blow again to create your gyre. Where do the items end up?
d. Imagine there is something like an island or a continent in the way of your currents. How do you think that would change the way the water moves?
e. If you want, add something like a rock or another large item to model this.

If you want to learn more about weather, the *Ocean!* StoryMap includes links to a game you can play.

5. Examine the map in Figure 2.6. Which currents and gyres are nearest to you?

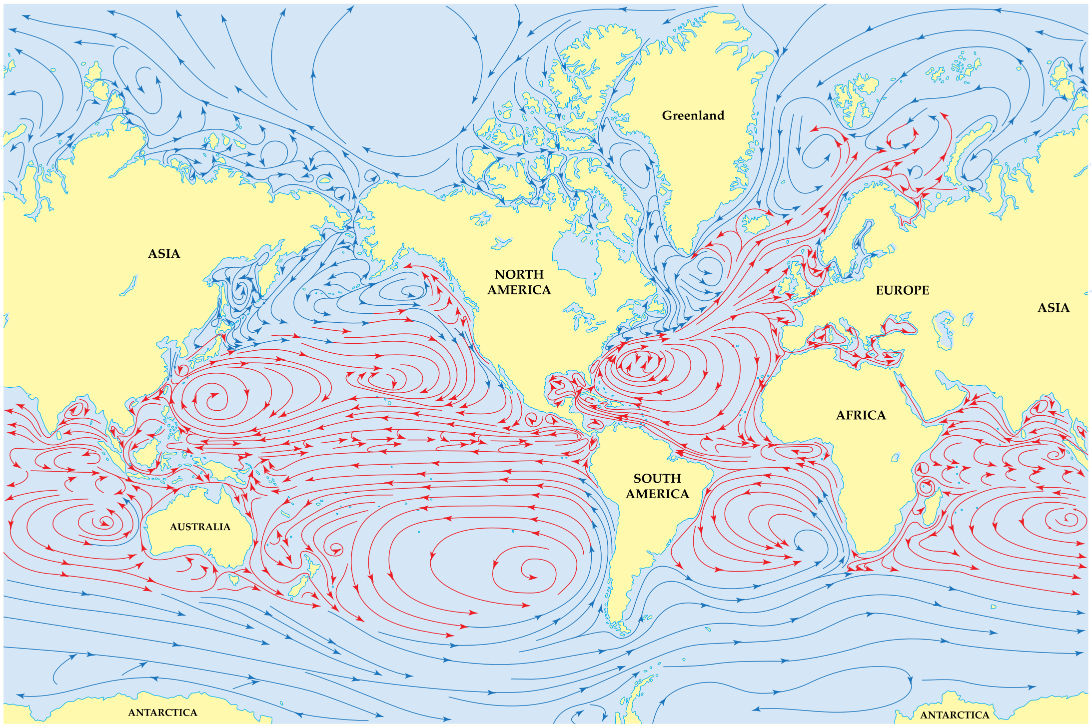

Figure 2.6: Map of surface currents on the ocean.

6. Using the map, pick a place across the world from you and try to trace how water that came from your community might make it to that place. If you learned in the Discover activity that your watershed empties into the ocean, start where it enters the ocean and try to find currents that could move the water from your community to a distant location.
7. Read Kālewa's thoughts about living on an island and how the water of Hawai'i connects with places far away.

Kālewa says . . .

The ocean connects us as humans. Even if we never meet each other in person, we can understand that the ocean's saltwater touches the shores of where we live, from continents to islands and **atolls**. The ocean provides us with the resources that sustain and nourish us; we play a role in the ecosystem and are responsible for caring for those waters.

Part 2 Task 1

From the lens of Native Hawaiian philosophy, the *Moana* (Pacific Ocean) is not just a vast expanse of saltwater but a living entity that binds, connects, and sustains all life. It is a bridge rather than a barrier. The ocean surface currents, or the pathways of the *Moana*, are like the veins of a body, pulsating and circulating life throughout, linking distant shores and the people who reside upon them.

Currents are the surface maps of open ocean voyaging harnessed by Pacific Islanders. Currents can indicate heat, cool, forthcoming weather, and even pockets of fresh water coming up deep from the ocean floor. In the ancient *a kānaka maoli* (Native Hawaiian) worldview, the *Moana* wasn't an empty expanse but a vibrant superhighway filled with signs, patterns, and destinations.

The ocean surface currents are intimately linked with the stars above and the year's seasons. *Kālai wa'a* (master navigators) would read the stars and understand the shifts in currents, winds, and even the behavior of marine life. Each current, each pathway on the ocean, carries with it a *mo'olel*o (story), a legend, a memory of ancestors who once voyaged these same routes.

8. With your team, discuss:
    a. How does the global water system connect people around the world?
    b. How do you think prevailing winds and ocean current gyres might affect shipping and airplane routes, weather systems, and the living things in the ocean?

Find out More!

Other things are also part of the movement of water, including tides, evaporation, underwater earthquakes and volcanoes, and deepwater currents. To learn more please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Act: *How can we be a positive part of the global water system?*

Water has been mixing since there was water on Earth. But sometimes the movement of the water system moves other things as well. You will learn more about this in the next task. But first it is important to link what you learned about your local watershed and ocean currents.

1. Take out your *Ocean and Water System Diagram*.
2. Examine it and think about the relationship of your community's water system with rest of the planet. For example:
   a. How do people and other living things depend on the water system?
   b. What responsibility to keep water clean do people in one place have toward people and other living things in other places?
3. Examine your *Ocean Identity Map* *Hopes* and *Concerns*. Do you notice anything that might depend on the movement of water?
4. Read Kālewa's ideas about how to be a responsible **steward** of water. A steward is someone who cares for the environment and helps manage resources wisely.

Kālewa says . . .

From the Native Hawaiian perspective, *wai* (fresh water) is a profoundly sacred resource, deeply honored and safeguarded across generations. It embodies the essence of life, connectivity, and spiritual sustenance. For students aspiring to become responsible stewards of our global water system, here's some valuable guidance rooted in Hawaiian traditions and worldviews.

First, approach the care of water with reverence and thoughtfulness. It's essential to honor both traditional wisdom and modern scientific knowledge. Combining these approaches allows you to tackle the complex challenges surrounding water issues. Both ways of understanding are important for water conservation and watershed management.

Understand that the privilege of using water comes with *kuleana* (responsibility) to protect it. Use water mindfully, avoid wasteful practices, and advocate for policies prioritizing water conservation and quality over individual interests. Engage in sharing and listening to water stories from your community and worldwide. Water stories reveal the profound emotional and cultural connections people have with water, offering guidance and inspiration for sustainable actions.

While water challenges are global, solutions often originate at the local level. Always consider the broader implications of local water decisions. Engage with your community, educate them about the significance of water conservation, and initiate or participate in projects promoting sustainable water use and protection.

5. Think quietly to yourself: What is one thing you have learned that you think is important for people to understand about the global water system?
6. Choose one person, whether it is a friend, family member, or someone in your community. Explain to that person how your community's water system relates to the global water system. Make sure you make it clear how this connects to their daily life.
7. Ask the person to share their thoughts on how to be a steward of the water system.

Task 2: How do circulating water pollutants affect our planet?

The global water system moves **pollutants** as well as water. Pollutants are harmful or poisonous substances that pollute something such as water or air. In this task you will ***discover*** more about types of water pollutants and which ones might be coming from your community. You will investigate to better ***understand*** how pollution affects the **organisms** or living things in the ocean. Then you will ***act*** to improve the pollution problems you found.

Discover: *What pollution might be coming from my local area?*

There are many types of pollution that enter waterways. Some are easy to notice, such as a plastic container or bag floating on the water. Some are more difficult to notice, such as chemicals or **microplastics**. In this activity you will be exploring more about water pollution in your local area.

In Task 1 you learned about how water moves through your local area and, in many cases, into the ocean. In this task, first you will model how pollutants might mix into that water. Then you will search for evidence of pollutants in your area.

1. Read and follow the instructions in *Modeling Water Pollution*.

Modeling Water Pollution

How does pollution from your community end up in the ocean? Think back to your watershed investigation in Task 1. You noticed how water flows in your community. When pollutants enter streams or rivers, they may eventually reach the ocean.

You will now model how three different types of pollution might reach the ocean. You may want to take out a piece of paper or a notebook, or find some other way to record your results.

Creating Your Model

Before you start to model pollutants and how they enter waterways, you will first need to set up a watershed model. As you know from Task 1, watersheds can be

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very large and can include many different types of land and water. For this model, you will make things simple.

a. Take out the container of water you used in Task 1. This will be the waterway in your model.
b. Find a piece of waterproofed cardboard, plastic, or another item you can place on an angle next to your water container. This will represent the land area near the waterway. Figure 2.7 shows an example.

Figure 2.7: Example of the setup for a watershed model.

Marine Debris

Debris are small items or bits of garbage that end up being blown by wind or pushed by water into waterways. Debris can be many different types of things—pieces of plastic, cigarette butts, wrappers, or even fishing nets. Debris can be very tiny, such as a small paint chip, or large items like tires or refrigerators, or even an abandoned boat.

a. Find a piece of plastic, such as a plastic bottle, that is being thrown away.
b. Cut it into small pieces to represent debris.
c. Place a few small pieces of plastic directly in the water container. What do you think that might be modeling?
d. Place the other pieces on the angled surface.
e. Try to blow the plastic toward the water, to model wind. Does it reach it?

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f. Use a watering can or cup of water in your hand and let it drip out to model rain. Can the rain wash the debris into the water?

Marine debris is sometimes thrown directly into a waterway or the ocean, like you modeled by putting the plastic directly into the water. Sometimes it is blown by wind or washed by rain into a waterway, like you just modeled.

Figure 2.8: Example of some marine debris.

Chemical Pollution

Chemical pollution is when chemicals from industry, farming, or households enter the water cycle. Chemical pollution includes manufactured chemicals, pesticides, detergents, oil, mercury, and other chemicals.

a. Use cooking oil or another liquid substance to model chemical pollution.
b. Place a small amount of your substance directly into the water. What do you think that is modeling?
c. Place a small pool of oil on your angled surface and place the surface next to your water container, like you did when you modeled marine debris.
d. Model wind. Does the oil get blown into the water?
e. Model rain. Does the oil get washed into the water?

Too often, chemicals are released directly into waterways through industrial waste, oil spills, or other sources. Even some types of sunscreen people wear can be chemical pollutants if they are washed off into the water when the people are swimming. Chemical pollution can also reach waterways by being washed into them.

Figure 2.9: Trying to clean up after chemical pollution from an oil spill.

Nutrient Pollution

Nutrient pollution is when excessive **nutrients** flow into the water supply. Nutrients are substances that help living things survive and grow. When thinking about nutrient pollution, nitrogen and phosphorus have been found to create the most problems. These nutrients can come from **fertilizer runoff**, waste from animals (like poop from dogs or pigs), or human waste such as from sewage treatment plants or septic systems. Runoff happens when nutrients like fertilizer wash off of fields or lawns when it rains. You will now model this.

a. Take a small cup of water and add food coloring to it.
b. Soak a sponge in the water and then place it on the angled surface.
c. Model rain over the sponge. What do you observe?

The colored water represents fertilizer that is used on farms and lawns. Fertilizer can run off when it rains, if too much is used. The more fertilizer used, the more likely it is to run off and enter the waterways.

Figure 2.10: Field with water running off which might contain nutrient pollution.

Like marine debris or chemical pollution, nutrient pollution can also directly enter the waterways, or be blown or washed there. If you want to model this, you can use salt or sugar to represent the nutrient pollution and then follow the directions for modeling marine debris.

In the Understand activity you will learn more about what happens to marine debris, chemical pollution, and nutrient pollution when they reach the ocean. For more information about these types of pollution, visit the *Ocean!* StoryMap.

2. With a partner, a small group, or your whole team, take a piece of paper and divide it into three columns.
3. Label the columns "Type of Pollution," "Description," and "Location."
4. Read *Water Pollution Sources Investigation* and together investigate sources of water pollution in your local area.

Water Pollution Sources Investigation

Picking Your Investigation Area

You will need to pick an area outside where you can move around. You can limit your investigation to the area just outside of where you are, such as a schoolyard, or you can go farther into your local community. If you have a waterway nearby, try to investigate that in addition to the land.

You will be investigating the three types of pollution you modeled: debris, chemical, and nutrient pollution. Direct observation may be the best way to find out things that might be polluting the waterways in your area. If you can, go outside and move around your investigation area and search for evidence of the three types of pollution.

Marine Debris

a. Search carefully for any items you can find that are small enough that they could be blown by wind or pushed by flowing water. For example, a food wrapper, a plastic bottle, a small bit of a car tire, a chip of paint, or a cigarette butt.

b. When you find an item, even if it is very small, write "debris" under *Type of Pollution*. Then describe the item in the *Description* column and write where you found it in the *Location* column.

c. If it is safe to do so, pick up the pollution and discard it in a trash or rubbish bin. Make sure you either wear gloves or wash your hands thoroughly afterward.

⚠ **Physical Safety Tip**

It is helpful to stop pollution from entering waterways, but only pick it up if it is safe to do so. Ask an adult for guidance if you are unsure.

Chemical Pollution

a. Search carefully for evidence of chemical pollution. You might want to investigate:

- Any place you find pooled oil or other chemicals
- Leaking fluids from cars or dumpsters
- Any local industry that might be releasing chemicals into waterways

b. When you find any evidence of chemical pollution, write "chemical" under *Type of Pollution*. Then fill in the *Description* and *Location* columns.

⚠ **Physical Safety Tip**

Do not touch or go near any chemical or nutrient pollution, it can be harmful.

Nutrient Pollution

a. Search carefully for evidence of nutrient pollution. You might want to investigate:

- Any waste you notice from animals
- Evidence that people are using fertilizer on their lawns or fields

b. When you find any evidence of nutrient pollution, write "nutrient" under *Type of Pollution*. Then fill in the *Description* and *Location* columns.

Alternative Investigation

If you are unable to move around outside, that is okay. Think carefully about things you have noticed when you have been moving around your community in the past. Make a note of the type, description, and location of any pollution you have observed.

5. Come together with your team and examine your papers to think about the pollution each group found.
6. Discuss with your team:
   a. What pollution did you find in your community during your *Water Pollution Source Investigation* that concerned you the most?
   b. Can you think of any way to stop this pollution from entering the waterways?
7. Add the types of pollution as new *Additions* to your *Ocean and Water System Diagram*. Connect them to the other elements in the system. For example, if you found debris that has been washed into a stream, draw an arrow connecting the debris addition with the stream element.
8. Examine your *Ocean and Water System Diagram* and think about how pollutants from your community can enter the global water system. Use the arrows you drew earlier between your *Removals* and *Additions*.

Understand: *What happens to pollution in the ocean?*

You now understand how water carries pollutants from your community, such as debris, chemicals, and nutrients, to the ocean. But what happens when those pollutants reach the ocean?

1. Go back to Figure 2.6 and with your team think about where pollutants from your community's watershed might go if they reach the ocean. Remember, water and pollutants often move and are mixed by currents. Can you trace a path for a pollutant you noticed during your *Water Pollution Source Investigation* to travel to another community across the world?
2. Read *At the Smithsonian*. If you were trying to understand pollution in the ocean, why do you think it would be important to sample beaches from around the world?

At the Smithsonian

Have you ever been curious about something? Martin Thiel is a scientist who is curious about ocean travelers and marine debris. An ocean traveler is a marine organism that attaches itself to a piece of floating marine debris and ends up traveling to a new location. Ocean travelers moving around on floating marine debris might become **invasive species** that can change ocean ecosystems if they are able to reach and colonize new coastlines. Invasive species are species that are introduced and are not native to a specific area.

But how could one person figure out what was happening with marine debris and ocean travelers all around the world? Martin knew he could only travel to a few beaches himself to investigate. But what if other people were curious as well?

Martin partnered with the Smithsonian and an organization from Chile called Cientificos de la Basura (Litter Scientists) to start a **citizen science** project called Ocean Traveler. Citizen science is a project in which anyone, whether or not they are professional scientists, can help gather scientific data.

Figure 2.11: Citizen science volunteers analyzing marine debris.

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For Martin's Ocean Traveler citizen science project, more than 2,000 teachers, students, volunteers, and scientists all came together to gather and analyze marine debris samples from more than 470 beaches between July and December 2022! As they shared their data, these researchers learned a lot about marine organisms floating on debris around the world.

For more information about citizen science projects related to the ocean, visit the *Ocean!* StoryMap.

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3. Take out your *Ocean Identity Map* and examine it. Do you notice anything in the ocean system that pollutants might harm? Turn to a partner and share your ideas.
4. Read *Ocean Organisms Investigation* and follow the directions.

Ocean Organisms Investigation

Pollution caused by humans has been found all over the ocean. Pollution has a huge effect on living things in the ocean. In this investigation you will start to explore some of those effects.

a. Have each team member pick one living thing from the *Marine Organism Table* in Figure 2.12 to represent. Or, if you prefer, choose a different marine organism that is not listed. Try to pick as many different organisms as possible within your team.

Organism	Description
Oyster	Oysters eat by filtering tiny living things, such as **phytoplankton** and **zooplankton**, out of ocean water. They live in fairly shallow areas near the coast and help keep the water clear.
Stony Coral	Stony corals usually live in the sunlit part of the ocean and have a **symbiotic** relationship with a type of **algae** that helps provide food for them. They also eat phytoplankton and zooplankton.

Figure 2.12: Marine Organism Table. (continued)

Organism	Description
Phytoplankton	Phytoplankton, also called microalgae, live in the upper part of the ocean. They are **photosynthesizers** and form the base of the food web in most of the ocean, as well as in fresh water systems. Their growth is often limited by available nutrients. They are an important food source for many things.
Sea Otter	Sea otters breathe air and frequently dive from the surface to deeper water. They eat sea urchins, crabs, fish, and many other things. They live near coasts and rely on their fur to keep them warm.
Ocean Fish	Fish in the ocean vary widely in size. Small fish eat zooplankton and small bits of organic matter, such as fish eggs. Larger fish eat smaller fish. Different species of fish live at different depths and locations in the ocean.
Seabirds	Seabirds are often found along the coast, but some can fly thousands of miles without stopping on land. Seabirds can eat a variety of ocean organisms, including plankton, krill, and small fish.
Humans	Humans usually live along the coasts and inland from the ocean. They use the ocean for shipping, swimming, and as a source of food. Humans frequently eat ocean organisms such as oysters, fish, crabs, and seaweed.
Sea Turtle	Sea turtles can travel long distances, but are often found in relatively shallow coastal waters. Different sea turtle species eat different things, including crabs, seagrass, algae, and jellyfish.
Seagrass	Seagrass uses photosynthesis to grow on the bottom of the ocean in relatively clear water. Seagrasses are an important food source for animals, such as sea turtles. They are also an important habitat for animals such as fish. Seagrass captures carbon and is important for the fight against climate change.

Figure 2.12: (continued)

Organism	Description
Whale	Whales are the largest animals in the ocean. They eat many different things, from tiny zooplankton called krill to other mammals. When they die, whales provide an important food source for animals that live on the ocean floor.
Zooplankton	Zooplankton are tiny organisms found near the surface of the ocean and are moved by ocean currents. They eat phytoplankton and other zooplankton and are eaten by many organisms, from oysters to whales.
Crab	Crabs can live in many places, from beaches to the relatively deep ocean floor. Crabs eat many things, including zooplankton, algae, fish, and dead animals. Fish, sea otters, and turtles all eat crabs.

Figure 2.12: (continued)

b. Use a piece of paper or poster board and create a sign for the organism you are representing. Write the name of your organism and use drawings or words to represent what you know about the organism. You can use the description in the *Marine Organism Table* to help you. Make your sign as visually pleasing as possible.

c. Move around and examine other people's signs. If you find an organism that seems to relate to the one you are representing, stand or sit nearby.

d. Create a line of organisms that are linked to one another and stand or sit in this line.

5. Choose one team member, or someone outside the team, such as a teacher or another student, to read *Pollution Threat 1*, *2*, and *3* aloud. If understanding information read aloud is difficult for someone on your team, find another way to communicate the information.
6. Pay attention as *Pollution Threat 1*, *2*, and *3* are read aloud. For each type of pollution threat, if you think this might harm the organism you are representing, raise your sign and share how this pollution might affect the organism you are representing.

7. After each pollution threat discussion, make a note on the back of your sign about how the pollution might affect the organism you are representing.

Pollution Threat 1: Marine Debris Information

As plastics and other debris enter the ocean, they can create many different problems.

Gyre Garbage Patches

You remember that ocean gyres often move in large circular patterns. Although at the edge of a gyre the current may be moving quickly, in the center the water is relatively calm and still. This means when debris drifts into the middle of an ocean gyre it can stay there for a long time. There are at least five major garbage patches in the middle of ocean gyres. The largest is the Great Pacific Garbage Patch.

The plastic and other materials in garbage patches can block the sun and prevent phytoplankton production. The marine debris can entangle many types of animals, making it difficult for them to swim, eat, or fly. Animals can also eat the plastic by mistake, which can choke them or block their digestive tract.

Microplastics

Microplastics are bits of plastic that are so small they can be hard to see. Often larger plastic debris is broken down into microplastics by the sun, water, and movement of the ocean. There are also microplastic sources from people, such as the small fibers that are shed when washing synthetic clothing (like fleece or polyester), small bits of rubber from tires, small paint chips, and small beads from cosmetics, like facial scrubs.

Microplastics are so small that some can enter the bloodstream or tissues of animals. Microplastics can be toxic and affect the health of marine organisms and people. Plankton, filter feeding organisms, and shellfish may ingest microplastics. Because they are then eaten by other organisms, those organisms eat the microplastics as well.

Stop and Assess

Consider the biggest marine debris threats to the organism you are representing. Is it blocking sunlight, entanglement, choking, microplastics, or something else? Have each team member raise their hand if they think their organism might be harmed by this pollution threat. Have them share why this harm might be a problem for their organism and other organisms linked to it.

Pollution Threat 2: Chemical Pollution Information

There are many chemicals that present a potential hazard to living things.

Oil Spills

One type of chemical pollution you may be familiar with is when oil is released or spilled into the ocean. This can harm any living organism in the area, but is perhaps most harmful to seabirds, whose feathers become coated with oil making it so they cannot fly, and mammals like sea otters, whose fur becomes coated in oil making it so it no longer keeps them warm.

Biomagnification

One problem with releasing toxic chemicals into the ocean is that they can cause harm in ocean organisms and the people who eat them. **Biomagnification** means that some chemicals are concentrated in larger animals that eat smaller animals. A big fish like a shark, which eats smaller fish, concentrates the toxic chemicals from each of the smaller fish it eats.

For example, the toxic chemical mercury is naturally released into the environment, but it also is released because of human activities, such as burning coal for energy and using mercury to help extract gold during mining. As mercury enters the environment, almost every living thing is exposed to a little bit of it. But the more mercury an organism is exposed to, the greater the risk of harm. Biomagnification means that sharks, other large predators, and humans have a greater risk of suffering harm due to mercury or other toxic chemicals.

Stop and Assess

Consider the biggest chemical pollution threats to the organism you are representing. Is it oil spills, biomagnification, or something else? Have each team member raise their hand if they think their organism might be harmed by this pollution threat. Have them share why this harm might be a problem for their organism and other organisms linked to it.

Pollution Threat 3: Nutrient Pollution Information

There is a threat of **dead zones** when too many nutrients reach the ocean, especially in areas like gulfs, bays, and inlets where water mixes more slowly with the open ocean. Seagrasses are also often affected by nutrient pollution because of the decrease in water quality.

Dead Zones

When too many nutrients reach coastal waters, they can cause phytoplankton, or single-celled algae, to grow quickly. There is sometimes so much algae that it is visible and can look green or red. Some types can be toxic.

The algae can grow so much that it blocks the sunlight from reaching the ocean beneath it. This can kill organisms that rely on photosynthesis. In addition, after the algae dies, large amounts of oxygen are used up during the decomposition process—so much that the levels of oxygen in the surrounding ocean can drop all the way to nothing. This area without enough oxygen dissolved into the water for most organisms to live is called a dead zone. Dead zones can lead to the death of fish, crabs, oysters, and anything else caught in the zone.

Stop and Assess

Consider whether nutrient pollution might be a threat to the organism you are representing. Is your organism likely to be caught in a dead zone or be unable to grow because of bad water quality? Have each team member raise their hand if they think their organism might be harmed by this pollution threat. Have them share why this harm might be a problem for their organism and other organisms linked to it.

7. Examine all your notes on the back of your sign. If you want more information about any of the pollution threats to the organism you are representing, you can do more research on your own. You could research using the *Ocean!* StoryMap, which includes links to websites where you can learn more, you could find books or magazines with more information, or you could talk to an expert.

8. Use your hands or another method to have each team member show how worried they are about the overall threat of pollution to the organism they have been studying. For example, if you think the threat is low, you could hold your hands low. If you think the threat is high, you could raise your hands high.
9. Consider everyone's thoughts about the seriousness of the threats of pollution to ocean organisms.
10. Turn to the front of your sign and add drawings or words to show the pollution threats this organism faces.
11. Place your sign on a wall or table.
12. Have everyone move around the room and examine everyone's sign.
13. Read Kālewa's experience with pollution and ocean organisms.

Kālewa says . . .

Pollution profoundly impacts our beloved ocean organisms and ecosystems. When toxins and plastics drift into our waters, they poison the fish, shellfish, and corals that have sustained our communities for generations. Our *'ohana* (family) has witnessed the declining health of our precious *honu* (sea turtles) as they ingest plastic debris and are plagued with tumors from sewage runoff. The diminishing populations of *'opihi* (limpets) on the Hawaiian coastlines are often due to water contamination and excessive runoff. These changes disrupt the delicate balance of life in the *kai* (ocean).

As stewards of these waters, it is our *kuleana* (responsibility) to protect and restore the ocean for future generations. By embracing our ancestral wisdom, we strive to *mālama i ke kai* (care for the ocean) and to inspire others to join us in this sacred mission for the well-being of our *'āin*a (land) and our people for the generations yet to come.

14. Come back together as a team and discuss:
    a. Which pollution threats do you feel most concerned about?
    b. Add that information to the *Concerns* circle on your <u>*Ocean Identity Map*</u>.

Act: *How can we limit the ocean pollution caused by our community?*

You have learned about how pollution from your community enters the ocean and how it affects ocean organisms. Now you will decide what you would like to do to take action on the problems you have identified.

1. Consider the three types of pollution from the Understand activity and have each member of your team vote on the type of pollution they most want to prevent.
2. Examine the results. Is there a clear sense of which type of pollution your team would like to take action on? If not, discuss your ideas further until you can find **consensus**—a balanced decision that works for everyone. If you are having a hard time deciding, you can use your *Ocean Goals* or your *Hopes* or *Concerns* on your *Ocean Identity Map* to help guide you.
3. Examine your *Ocean and Water System Diagram*. You have listed the pollution you found as *Additions*. Use the diagram to think about how you can either prevent these *Additions* from reaching the ocean or remove them once they are in the ocean.
4. Have each group member take out a small piece of paper. Now that you have chosen a type of pollution to focus on, you will need to decide what you will do to help prevent it. Write down one action idea. For example, you could:
    a. Organize a cleanup of an area around your community.
    b. Plant plantings near the edges of a waterway to help filter runoff before it enters the waterway. Or create a low area with plants to allow water to slowly seep into the ground.
    c. Create signs or other ways of sharing with people that a waterway and any pollution it carries leads to the ocean.
    d. Talk to businesses or your local government about pollution you noticed.
    e. Educate others about a type of pollution and how it affects people and ocean organisms, using the signs you created.
    f. Come up with another idea that will help address your pollution problem.
5. Kālewa also shared these ideas to consider.

Kālewa says . . .

It all starts with our choices as humans, as consumers, and as participants in this world. Most of the world's ocean pollution is plastic, from fishing nets to toothbrushes, water bottles, and lighters. You have more power than you might think. Know that every small action adds up, and you can be a part of the solution. Start by reducing single-use plastics like water bottles, straws, and bags. Instead, grab a reusable water bottle and a cloth tote bag to use every day. Connect with and support organizations doing watershed and beach clean-up events. Lastly, support businesses and policies that prioritize eco-friendly practices. Your choices and voice matter!

6. Share your ideas with your teammates. Do other people have different ideas? Listen carefully to one another while you explain your perspectives about why different actions would be important. Try to build a team consensus about the action you will take.
7. 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?
8. Think about how each team member will help. Put their names with the steps they would like to help with.
9. 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

10. 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.
11. 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.
12. Put your plan into action.
13. 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?
14. Save your *Ocean and Water System Diagram*. You will need it in Part 7.

Congratulations!

You have finished Part 2.

Find out More!

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

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.

Algae: A photosynthetic aquatic plant; there are many different types, from one-celled organisms to what is commonly called seaweed

Atoll: A ring-shaped coral reef, island, or group of islands

Biomagnification: How chemicals are concentrated in larger animals that eat smaller animals

Chemical pollution: When chemicals from industry, farming, or households enter the water cycle

Citizen science: A project in which anyone, whether or not they are a professional scientist, can help gather scientific data

Consensus: A balanced decision that works for everyone

Coriolis effect: Deflection of air to the right or left due to the Earth's rotation

Cryosphere: Places on Earth where water is always frozen

Currents: Water flowing in a specific direction

Dead zone: An area that does not have enough oxygen dissolved in the water for most organisms to live

Debris: Small items or bits of garbage that end up being blown by wind or pushed by water

Downstream: Father away from the source of water; the direction that water flows toward

Fertilizer: A kind of nutrient to help plants grow

Groundwater: Water found underground in the soil or in spaces between rocks

Gyres: Ocean currents that move in circular patterns

Inclusive: Everyone can and is welcome to participate

Invasive species: Species that have been introduced and are not native to a specific area

Marine debris: Plastic or other non-biodegradable items that are polluting the ocean; they can range from tiny microplastics to floating nets to large items such as abandoned ships

Microplastics: Bits of plastic that are so small they can be hard to see

Nutrients: Substances that help a living organism survive and grow

Nutrient pollution: When excessive nutrients flow into the water supply

Ocean basin: A geographic area within the larger ocean, like the Pacific Ocean

Organisms: Living things

Photosynthesizers: Plants that take in sunlight and carbon dioxide to make food, and release oxygen in the process

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

Pollutants: Harmful or poisonous substances that pollute something such as water or air

Prevailing winds: Important winds that blow in the same general pattern and direction

Runoff: Water that runs off roofs, driveways, sidewalks, lawns, and agricultural lands, often picking up chemicals and soil in the process

Steward: Someone who cares for the environment and helps to manage resources wisely

Source: Where a body of water came from

Surface currents: The horizontal movements of water near the ocean's surface

Symbiotic: A description of relationship between species which benefits both

Tributaries: Smaller streams or rivers that join larger bodies of water

Tropics: The region surrounding Earth's equator; the region stretches from the Tropic of Cancer to the Tropic of Capricorn

Upstream: Nearer to the source of water; the direction that water flows from

Water cycle: The process of evaporation, condensation, and precipitation that moves water around Earth and its atmosphere

Watershed: An area of land where all the water flows together into the ocean

Waterways: Flowing bodies of water, such as a river or stream

Zooplankton: Tiny organisms found near the surface of the ocean and moved by ocean water; they eat phytoplankton and other zooplankton

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Part 3:

Ocean and Air

SUSTAINABLE DEVELOPMENT GOALS

developed by

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Smithsonian Science Education Center greatly appreciates the efforts of all the individuals listed below in the development of *Ocean! How can we create a sustainable future for the ocean?* Part 3. Each contributed his or her expertise to ensure this project is of the highest quality. For a full list of acknowledgments please refer to the acknowledgments section at the beginning of this guide.

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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 • 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 • Pen or pencil • Blue Carbon Game cards • Scissors • Colored tape (optional) • 2 sets of 20 small items each—paper clips, small stones, blocks, etc.	*Ocean and Air System Diagram* *Ocean Identity Map* *Notice, Think Wonder*	40 minutes	89
Act	Consider different perspectives on ways to take action to reduce carbon dioxide in the air.	• Paper • Pen or pencil	*Ocean and Air System Diagram* *Ocean Identity Map*	15 minutes	101

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) • Markers • Natural pH indicator (such as red cabbage, blueberries, raspberries, blackberries, grapes or plums) and boiling water and a strainer, or pH meter or strips • Acid, such as vinegar or lemon juice • Base, such as baking soda • For option 1: straw • 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) • 5 clear glass or plastic cups • Small digital scale (optional) • Markers • Acid, such as vinegar or lemon juice • Water	*Ocean Identity Map* *Ocean and Air System Diagram*	30 minutes + overnight + 15 minutes	110
Act	Find consensus and take action on ocean acidification.	• Paper • Pen or pencil	*Ocean Identity Map* *Ocean and Air System Diagram*	25 minutes + action time	113

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

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

Part 3 Task 1

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.

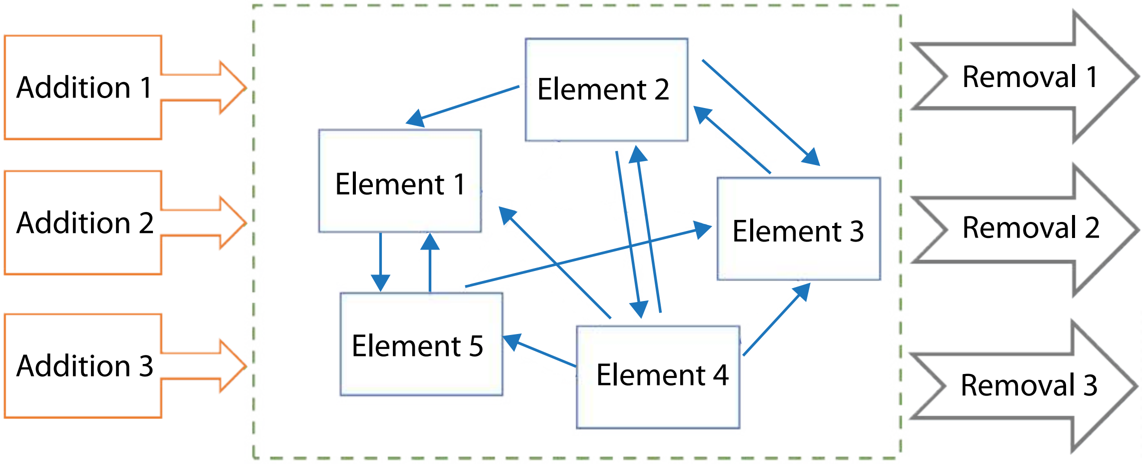

Figure 3.1: Sample system diagram including elements, relationships, boundary, Additions, and Removals.

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.

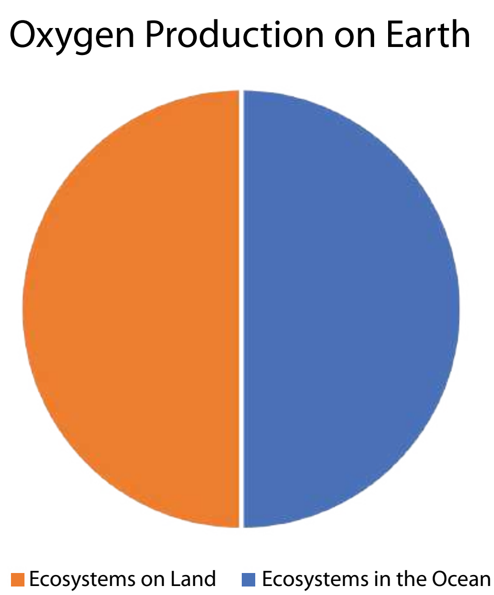

Figure 3.2: This chart shows the contribution of land and ocean ecosystems to Earth's oxygen production.

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."

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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.

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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.

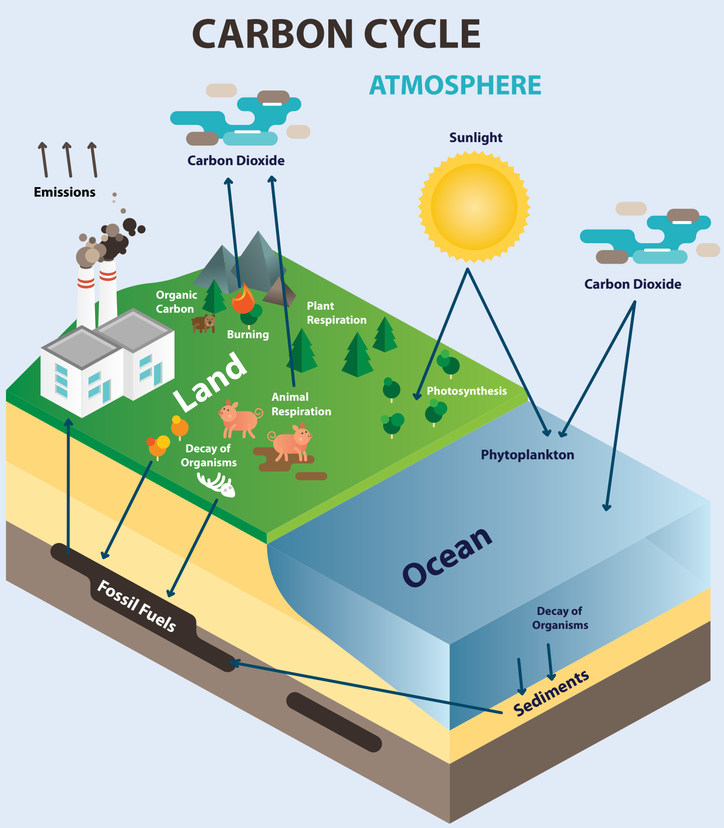

Figure 3.3: The carbon cycle.

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)

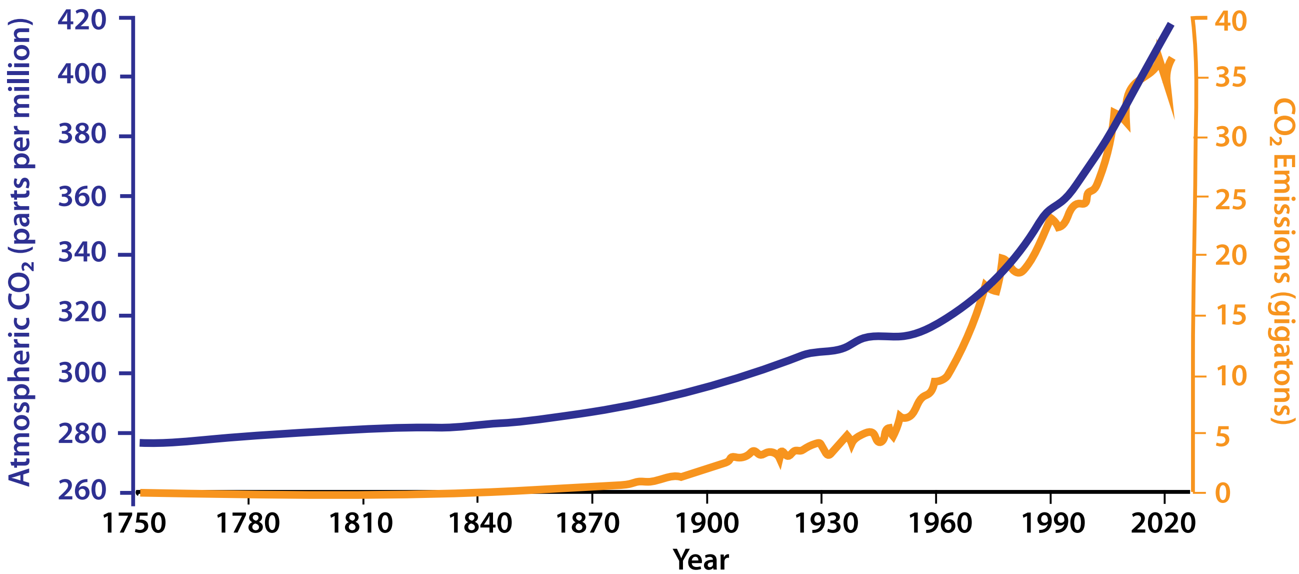

Figure 3.4: The change in atmospheric carbon dioxide over time[1].

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.

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You want to build a shrimp farm. You can choose to: Use: **2 mangrove spaces** Earn: **+2 people points**	Mangroves are a great place for baby fish to grow. This helps local people who fish. If there are at least 3 mangroves on the board: Earn: **+2 people points**	You want to build a new resort. You can choose to: Use: **3 connecting spaces (can be mangrove or empty)** Earn: **+3 people points**
You want to build a shrimp farm. You can choose to: Use: **1 mangrove space** Earn: **+1 people point**	Mangroves make excellent charcoal. You can choose to: Use: **1 mangrove space** Earn: **+1 people point**	You love being near the ocean and want to build a home there. You can choose to: Use: **2 connecting spaces (can be mangrove or empty)** 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: Change: **1 empty or built space to a mangrove** Earn: **0 people points**	You are an ecologist working to restore mangroves. You can choose to: Change: **1 empty or built space to a mangrove** Earn: **+1 people point**	You are an environmental activist working to restore balance. You can choose to: Change: **1 empty or built space to a mangrove** Earn: **+1 people point**
You run an ecotourism company helping tourists explore the mangroves. If there are at least 3 mangroves on the board: 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: Use: **3 connecting spaces (can be mangrove or empty)** 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: Use: **1 mangrove space** 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: Use: **2 connecting spaces (can be mangrove or empty)** Earn: **+2 people points**	People would like to be able to drive along the coast. You can build a road if you choose to: Use: **2 connecting spaces (can be mangrove or empty)** 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: Use: **1 mangrove space** 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?

⚠ 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.

Part 3 Task 1

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.

Social	Environmental
Ethical	Economic

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 *Ocean Identity Map* 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.

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.

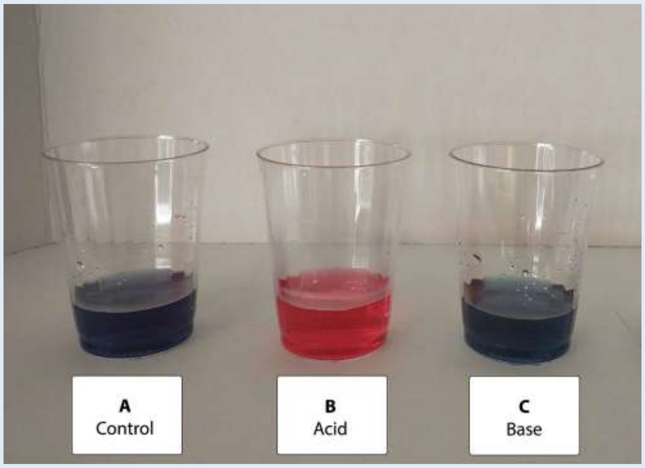

Figure 3.13: Example of Cup A (control), Cup B (acid) and Cup C (base) using the red cabbage indicator.

Part 3 Task 2

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.

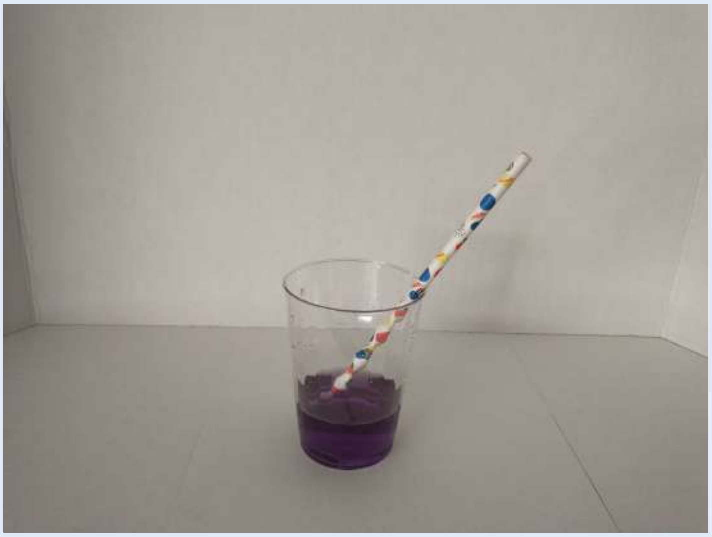

Figure 3.14: Adding carbon dioxide to Cup D using option 1.

⚠ 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).

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?

Part 3 Task 2

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.

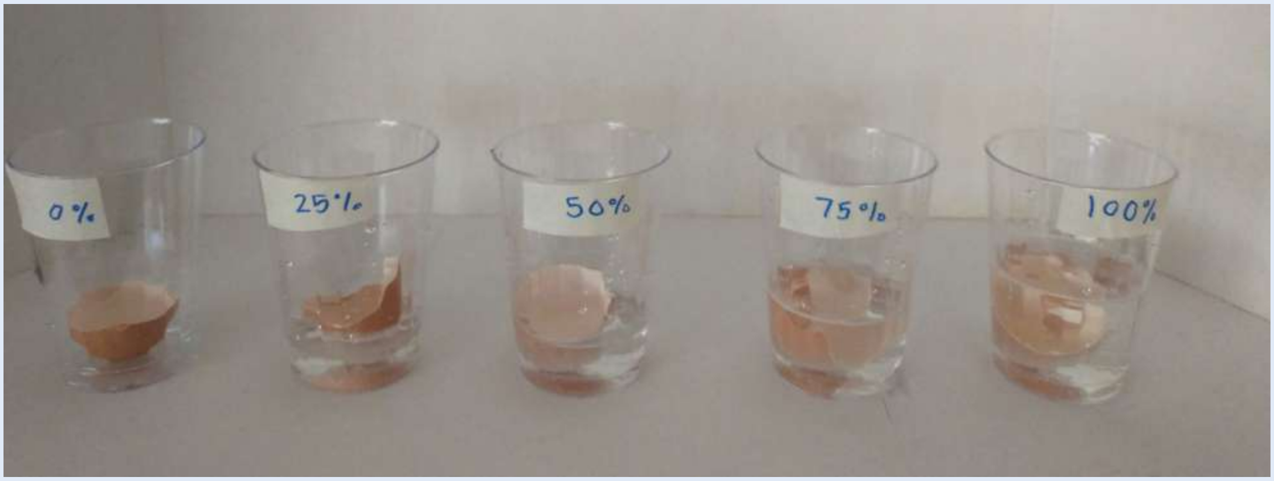

Figure 3.17: The Acidification Investigation setup with only acid added to each cup.

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

